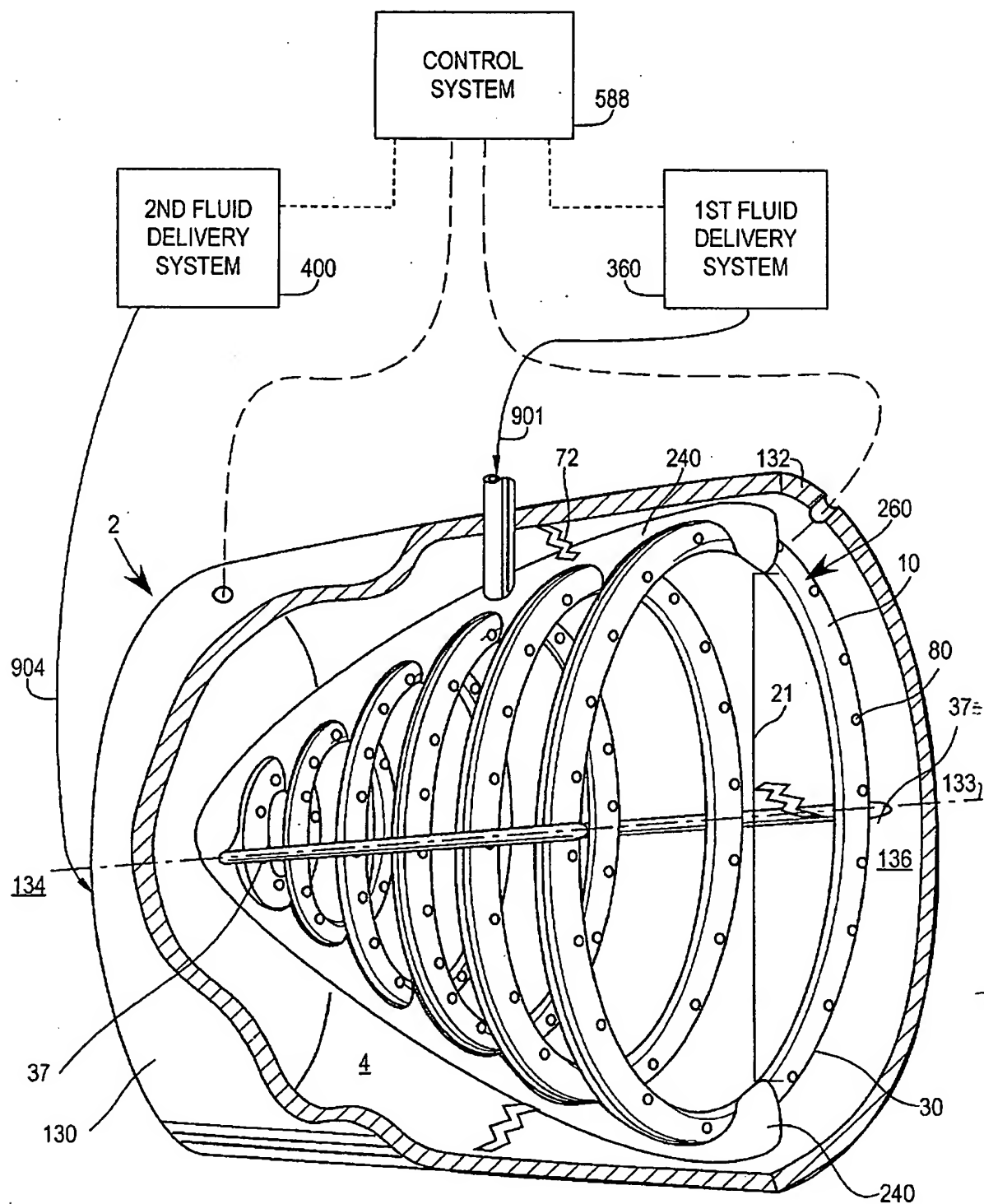Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 1

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

2/28

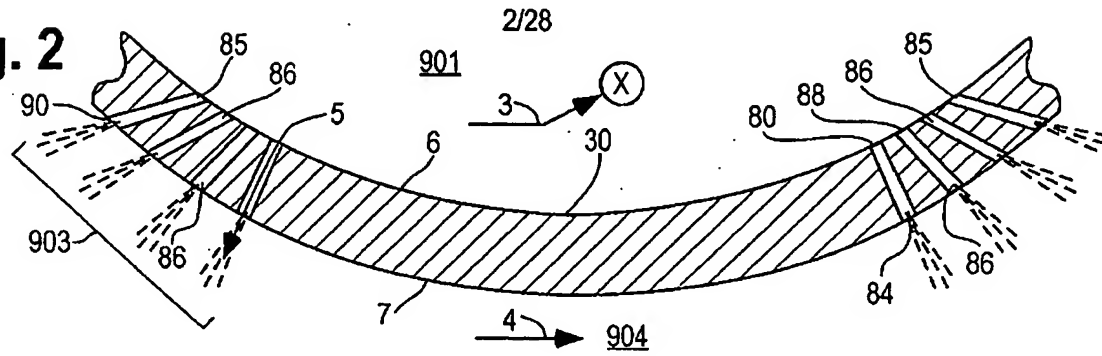**Fig. 2**
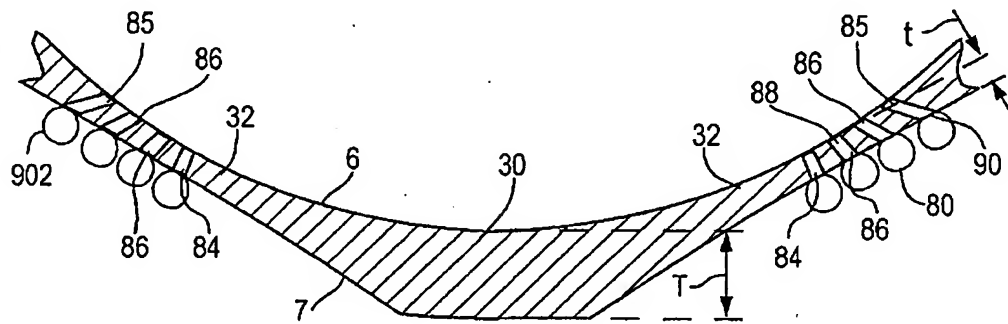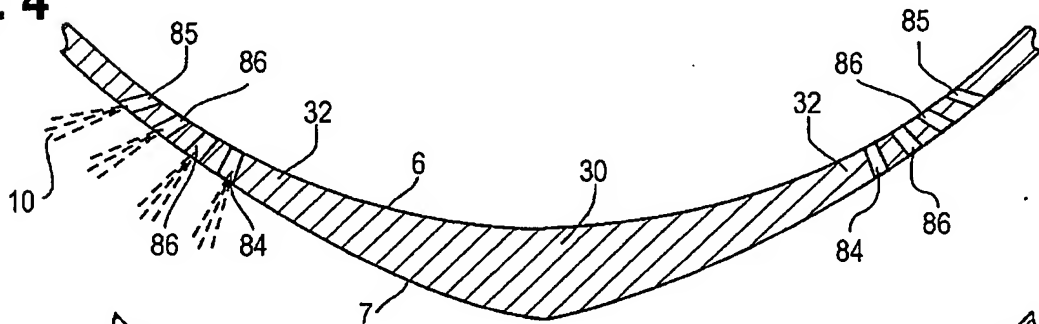
Fig. 3

Fig. 4

Fig. 5

Fig. 6

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2
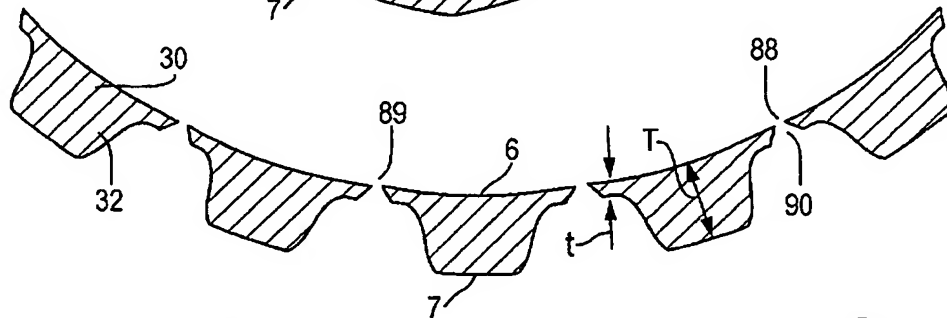
Fig. 7
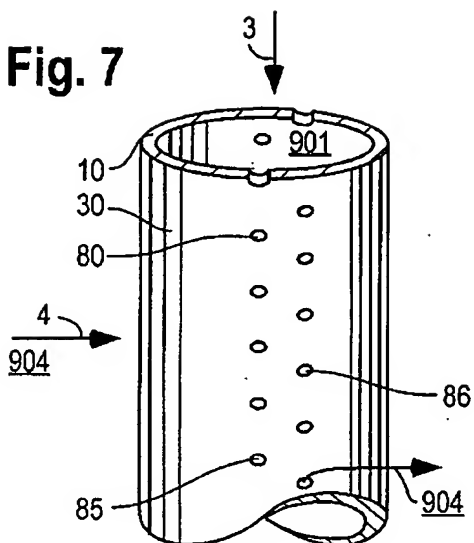
Fig. 8
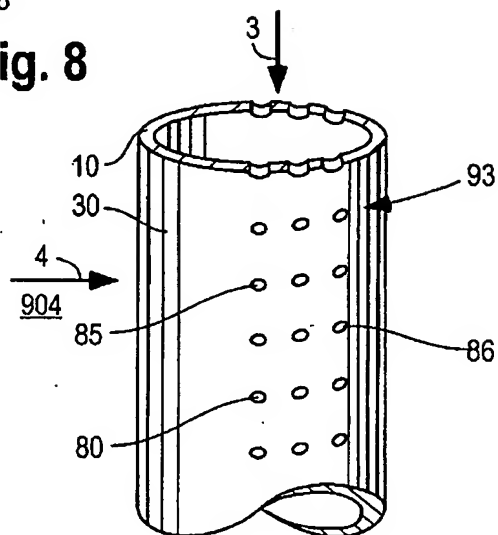
Fig. 9
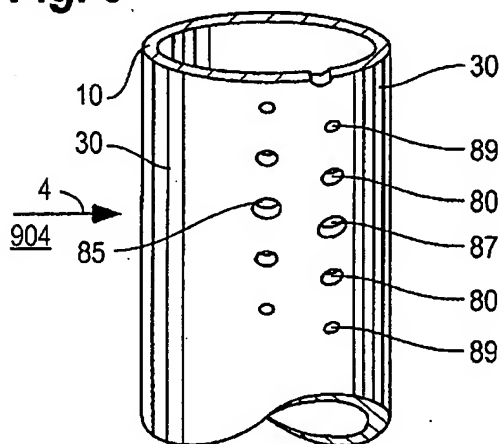
Fig. 10
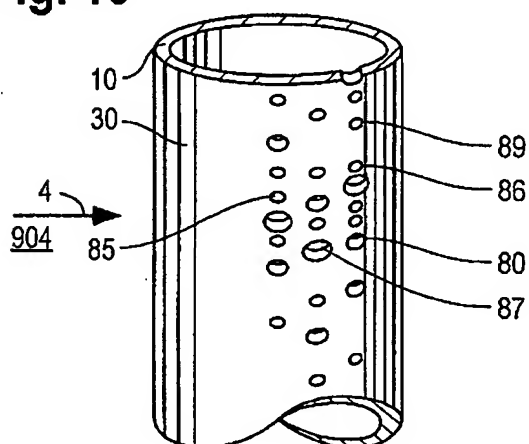
Fig. 11

Fig. 12

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 13

Fig. 14

Fig. 15
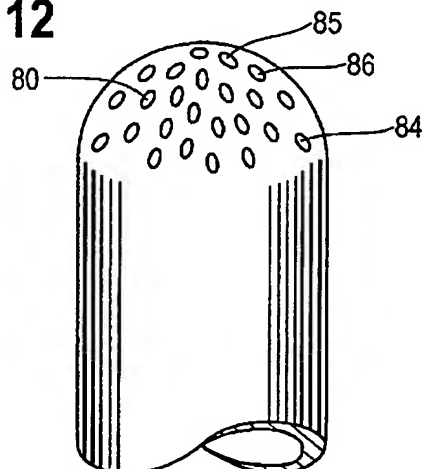
Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 16

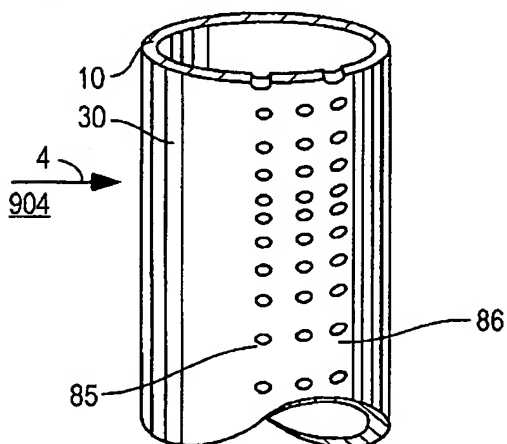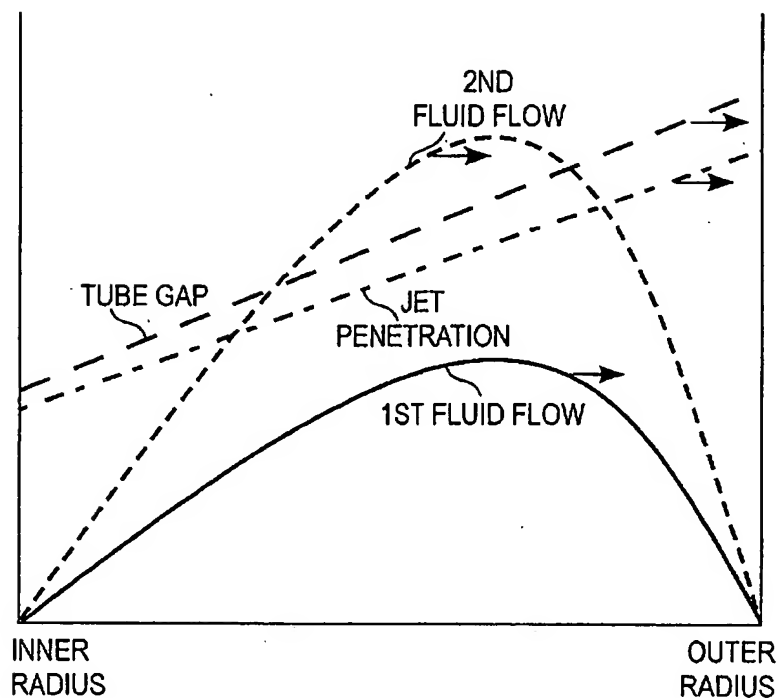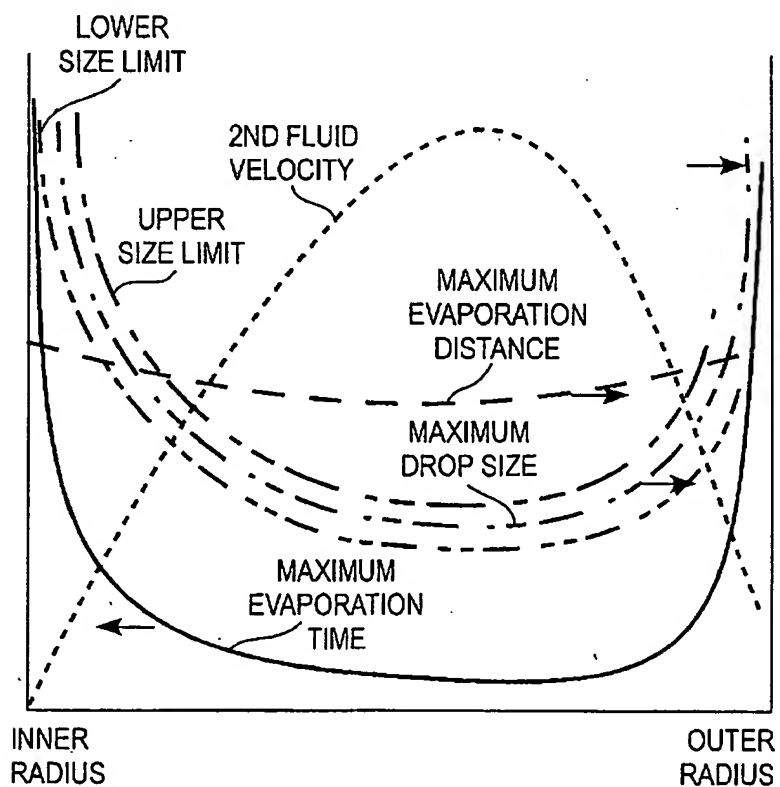## Fig. 17
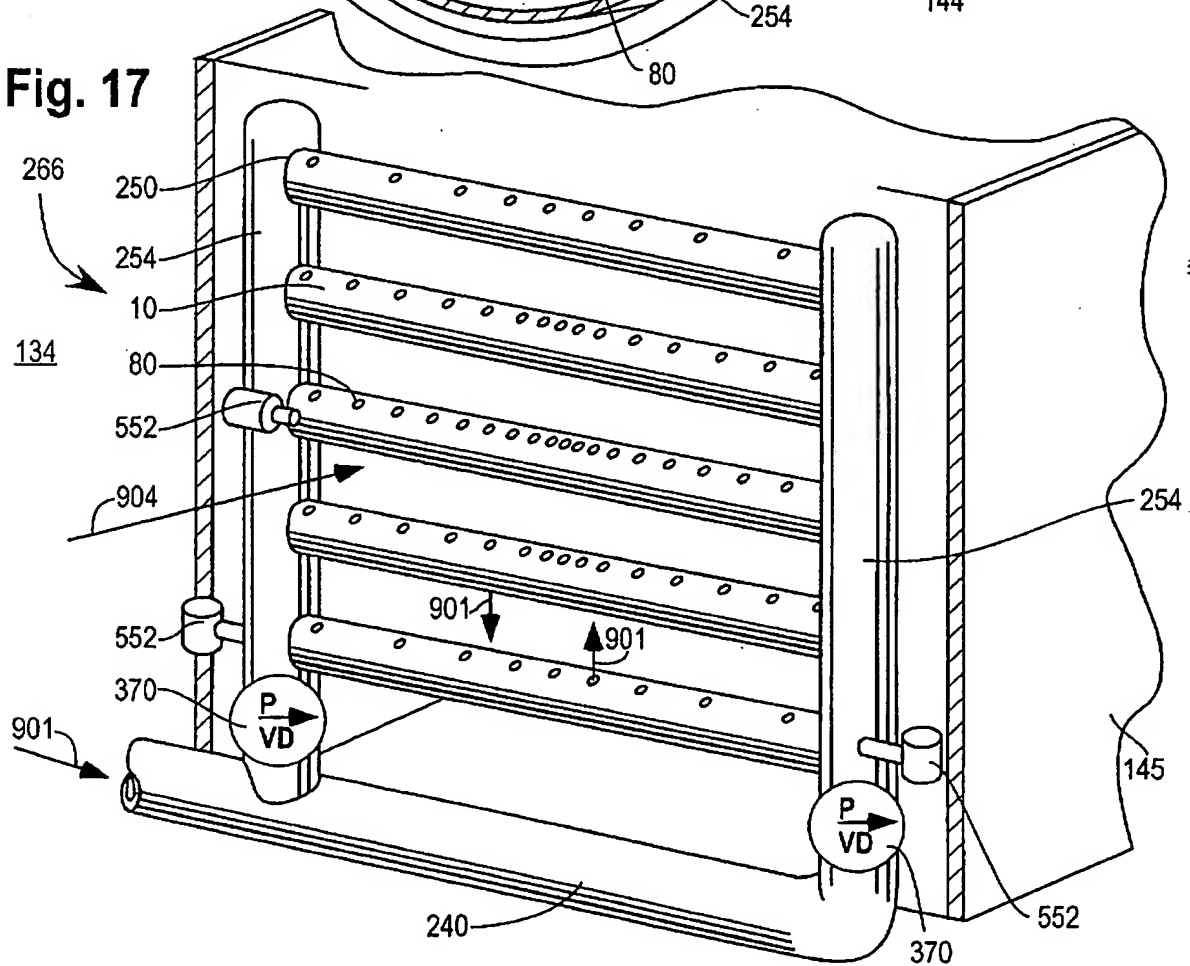
Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 18

2ND FLUID FLOW
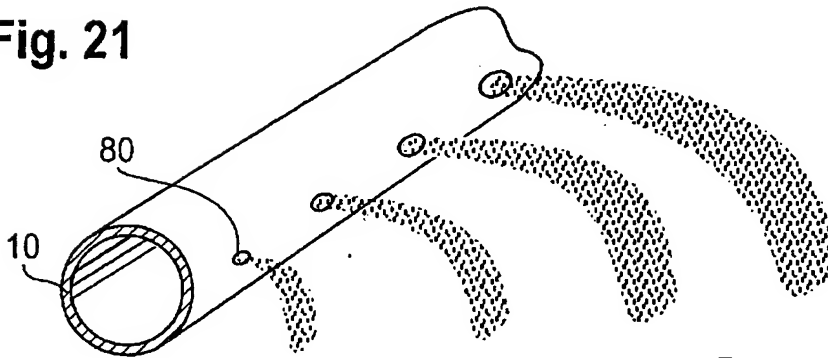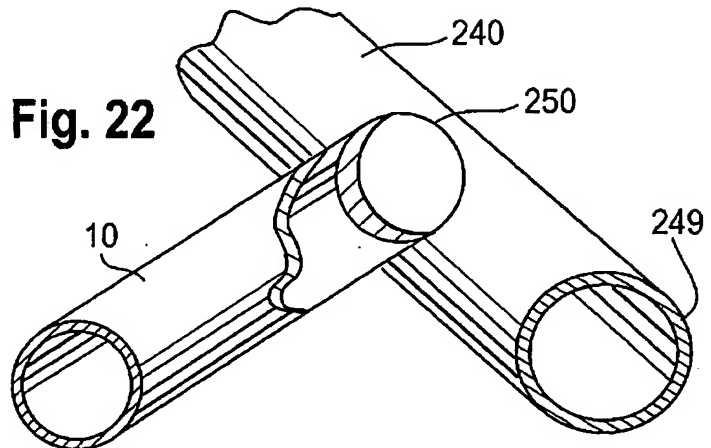
TUBE GAP

JET PENETRATION

1ST FLUID FLOW

INNER RADIUS

OUTER RADIUS

Fig. 19

LOWER SIZE LIMIT

2ND FLUID VELOCITY

UPPER SIZE LIMIT

MAXIMUM EVAPORATION DISTANCE

MAXIMUM DROP SIZE

MAXIMUM EVAPORATION TIME

INNER RADIUS

OUTER RADIUS

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 20

7/28

SECOND / FIRST FLOW RATIO

ORIFICE
SPACING

ORIFICE
DIAMETER

1ST FLUID
FLOW / ORIFICE

1ST FLUID
PRESSURE

INNER
RADIUS

OUTER
RADIUS

Fig. 21

80

10

Fig. 22

240

250

10

249

Fig. 23

8/28
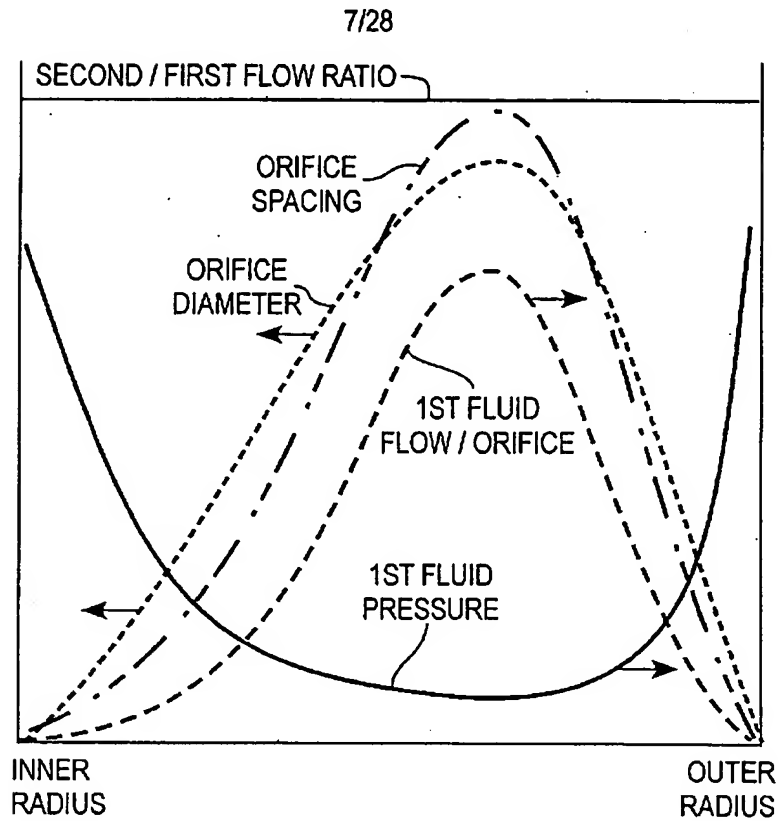
Fig. 24   **Fig. 25**
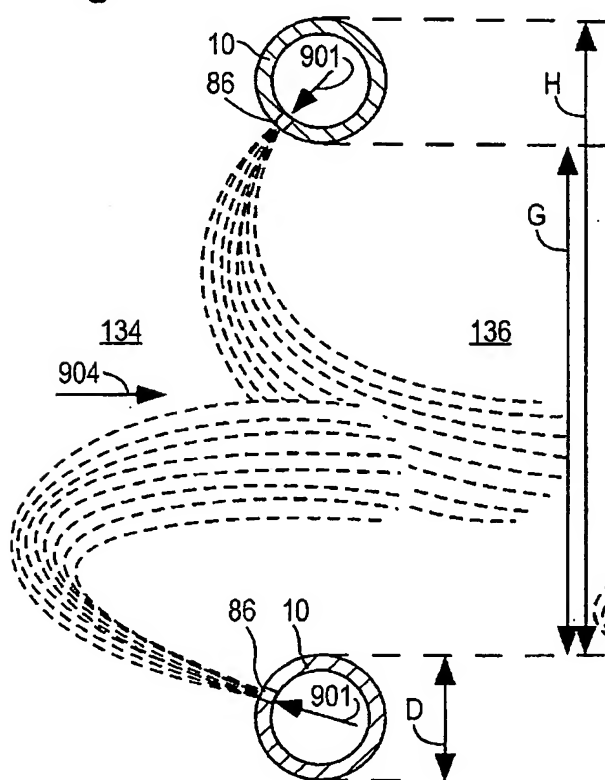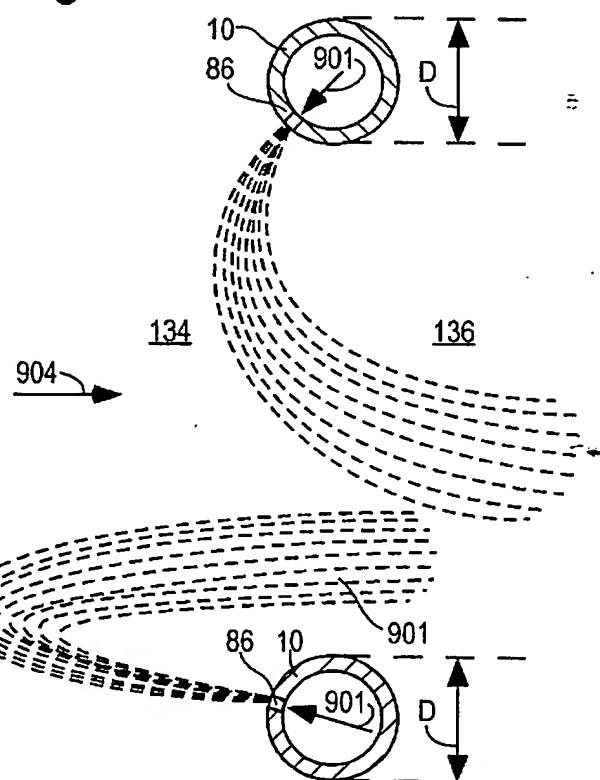
Fig. 26

Fig. 28

Fig. 27

Fig. 29

Method and Apparatus for Mixing Fluids
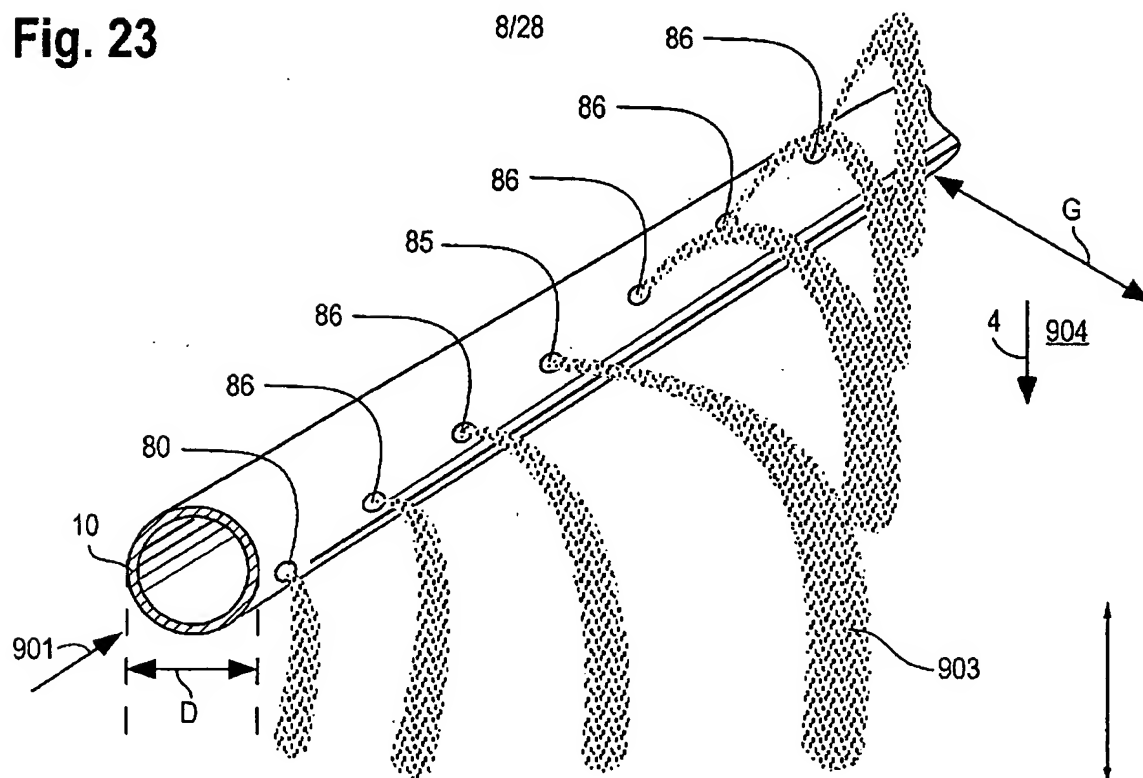Hagen et al.
Atty Docket:VAST.001CP2

10/28

Fig. 30

903
10
903
10
903

G
80
80

Fig. 31

903
10
903
10
903

80
80

Fig. 32
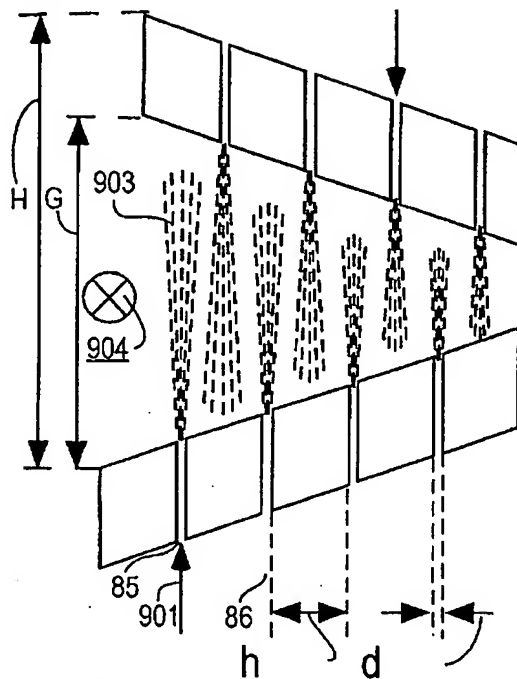
903
10
903
10
903

80
80

Fig. 33

903
10
903
10
903

80
80

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 34   39   11/28

Fig. 38

Fig. 39

Fig. 35

Fig. 40
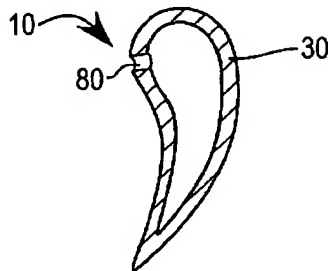
Fig. 36
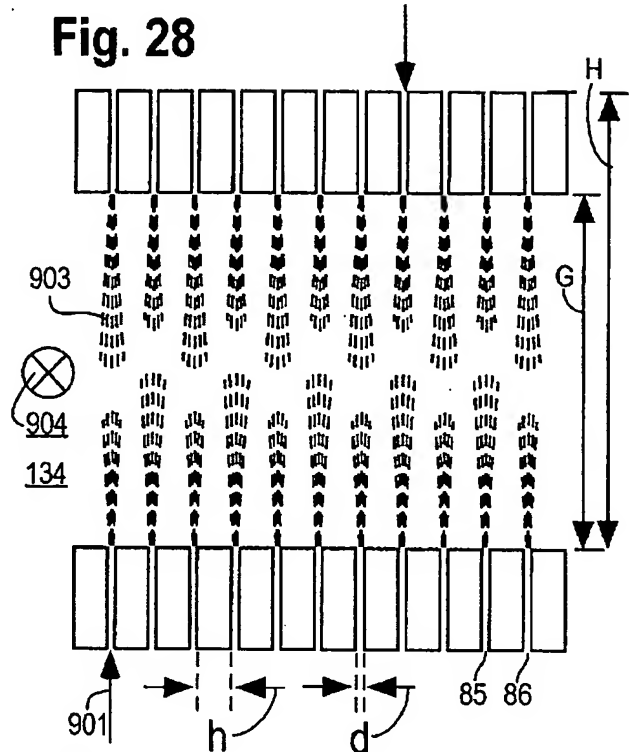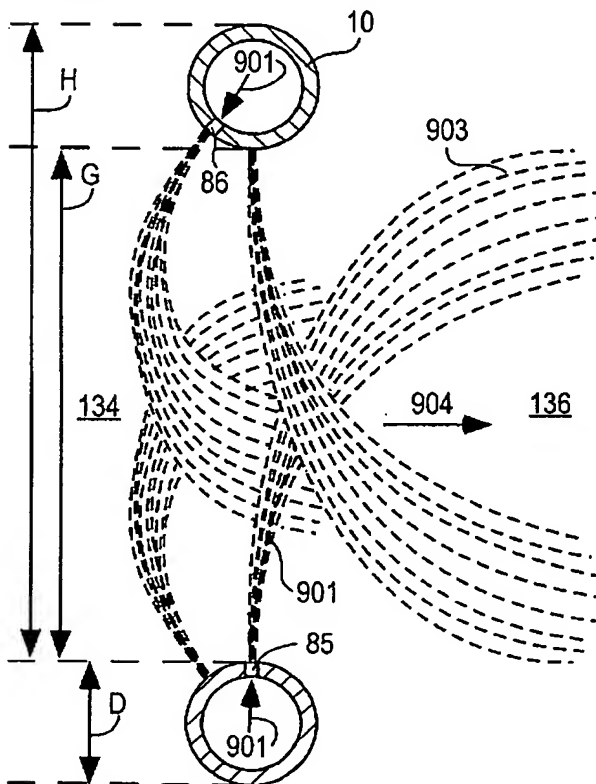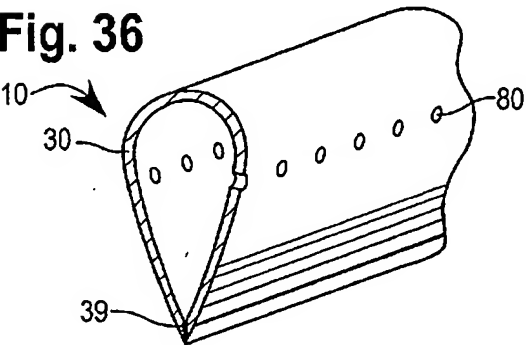
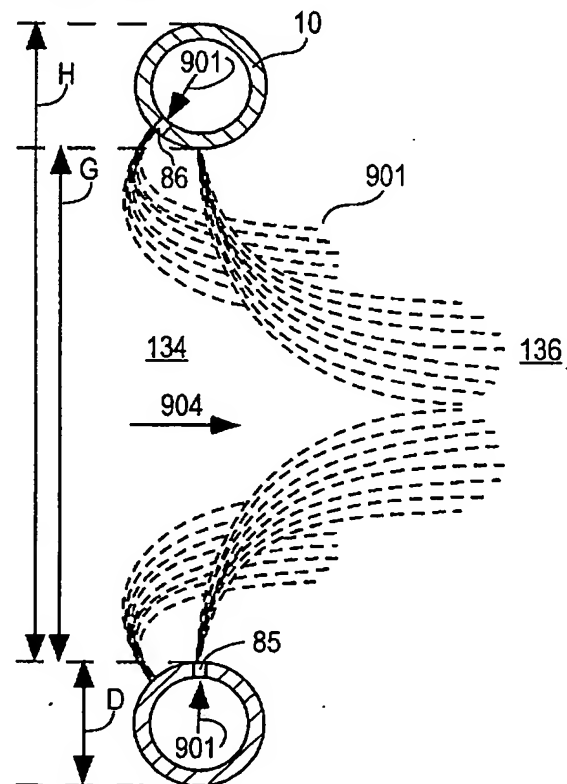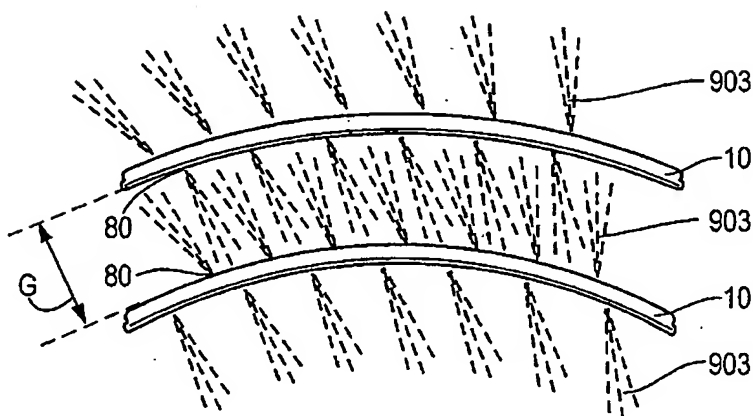**Fig. 41**
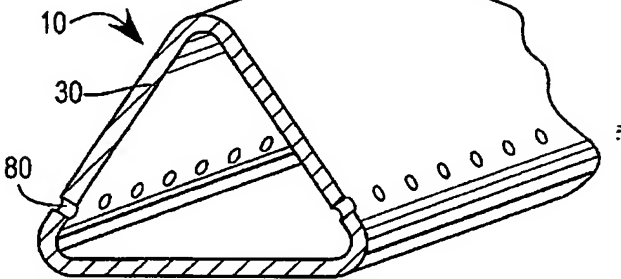
Fig. 37
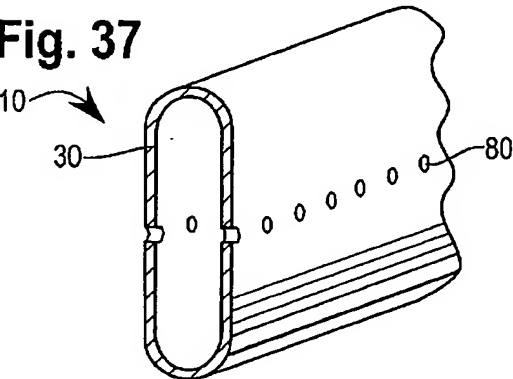
Fig. 42

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

12/28

Fig. 43

Fig. 44

Fig. 45

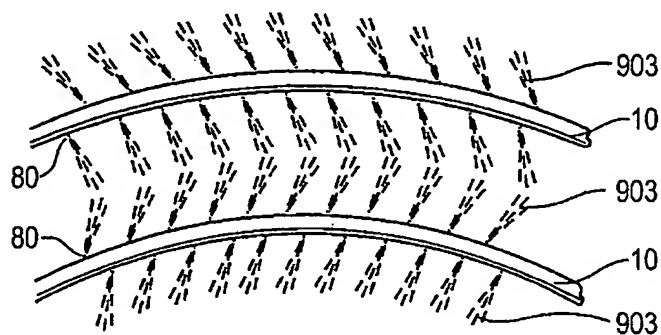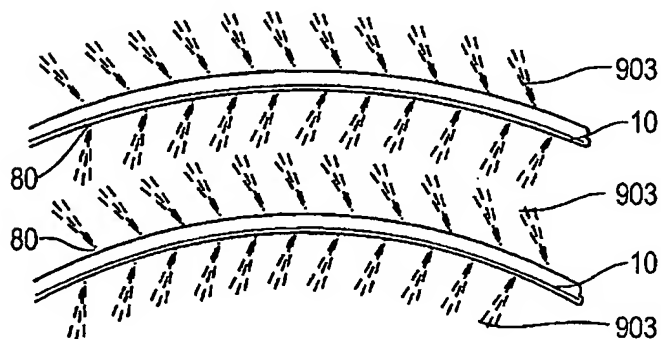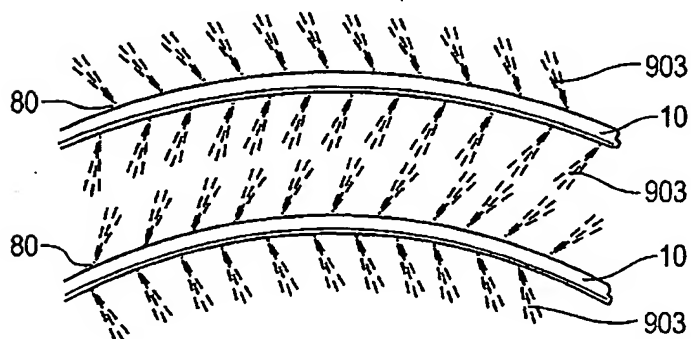Method and Apparatus for Mixing Fluids
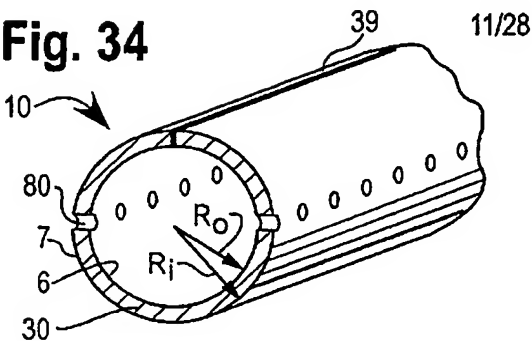Hagen et al.
Atty Docket:VAST.001CP2

Fig. 46

13/28
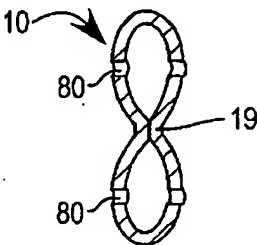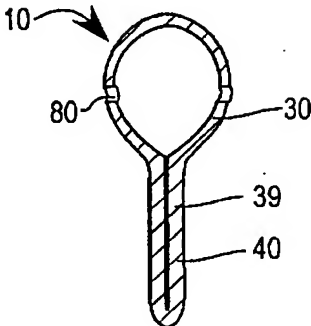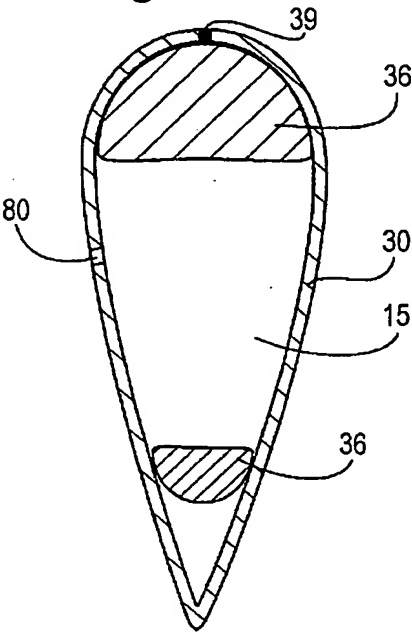
Fig. 48
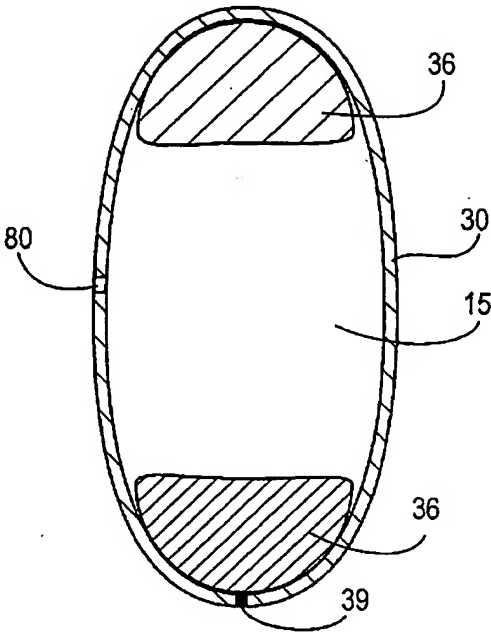
Fig. 47
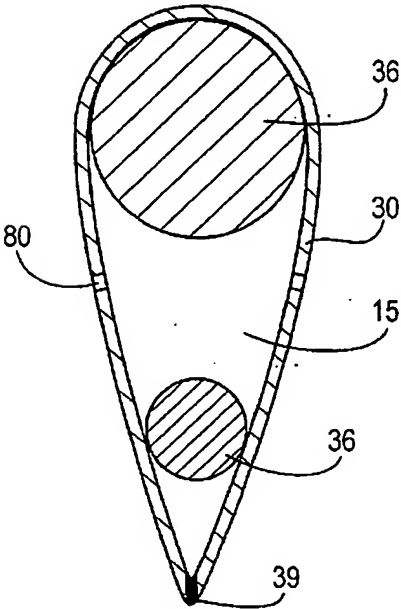
Fig. 49

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 50
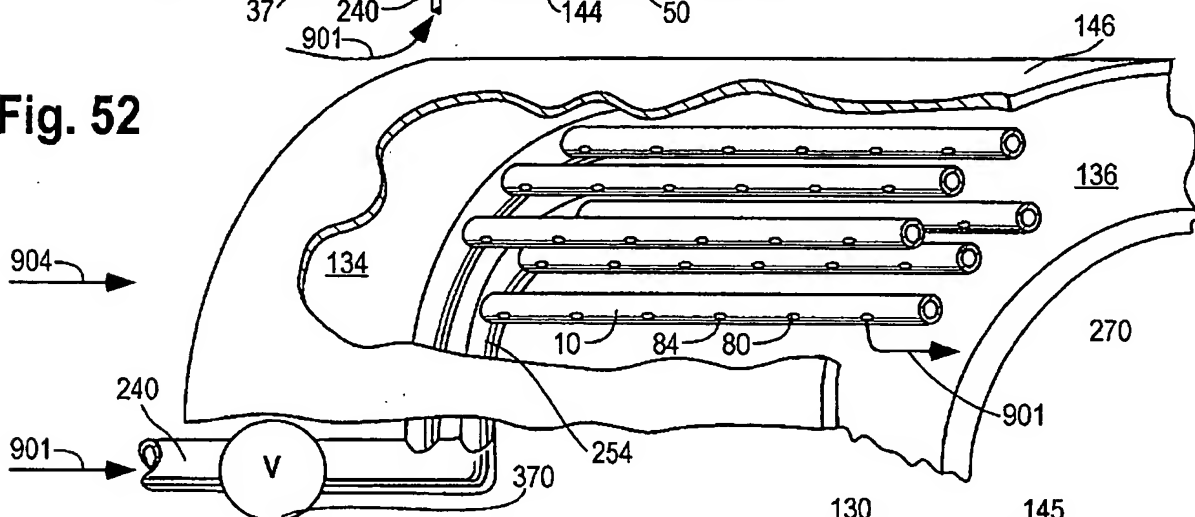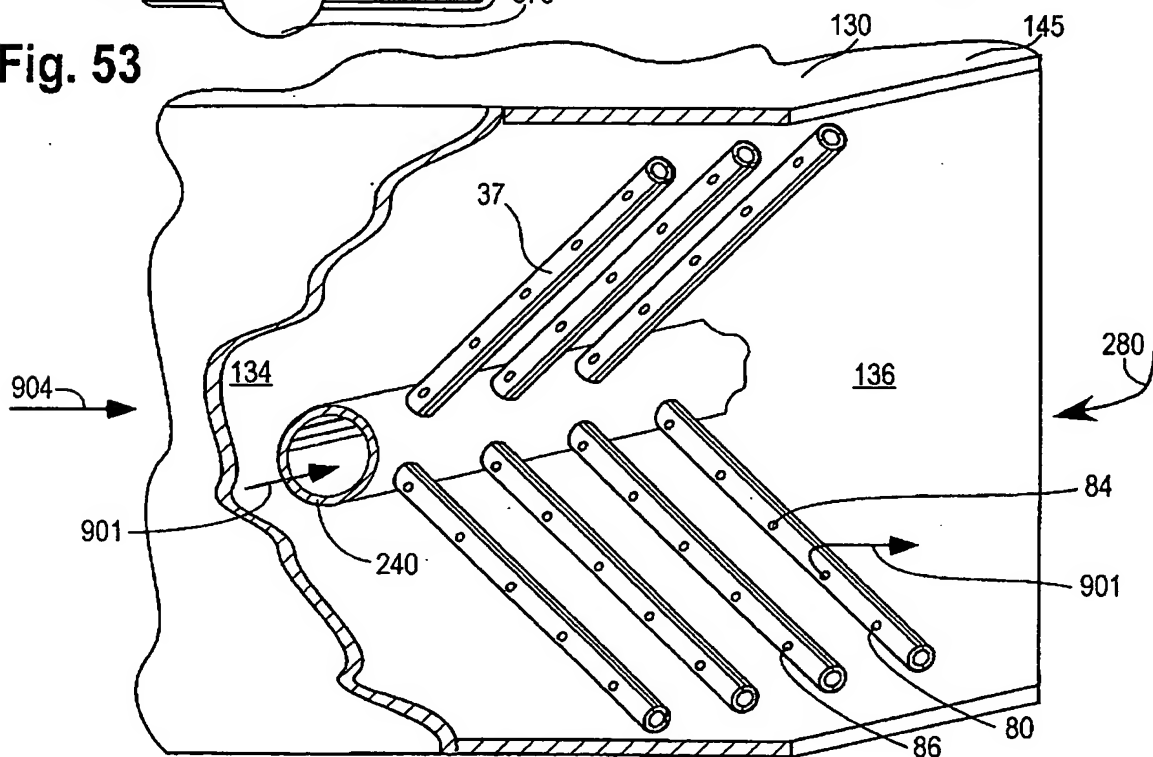
240 10   FIG 111B   14/28   265   240

134
904

136

37   240   144   50
901

Fig. 51

80
10
903

Fig. 52

146

136

904

134

10   84   80

270

240

901

V

370   254

901

Fig. 53

130   145

37

904

134   136   280

901   84

240   901

86   80

Method and Apparatus for Mixing Fluids
Hagen et al.
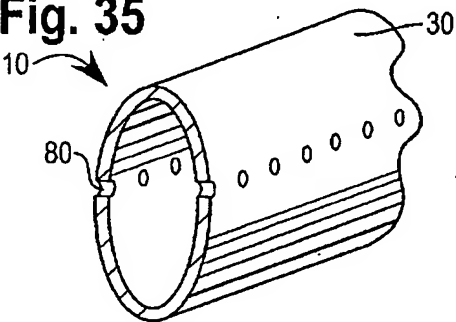Atty Docket:VAST.001CP2

Fig. 54
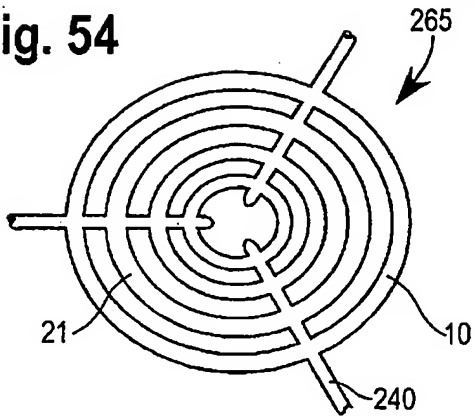
Fig. 57
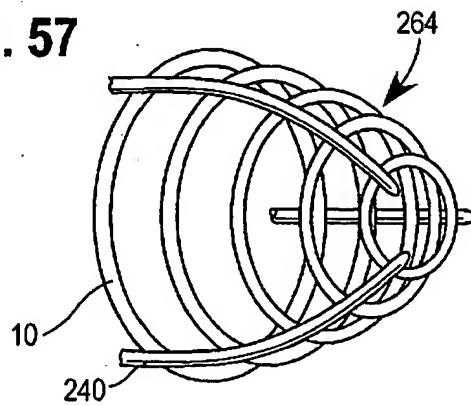
Fig. 55

Fig. 58

Fig. 56

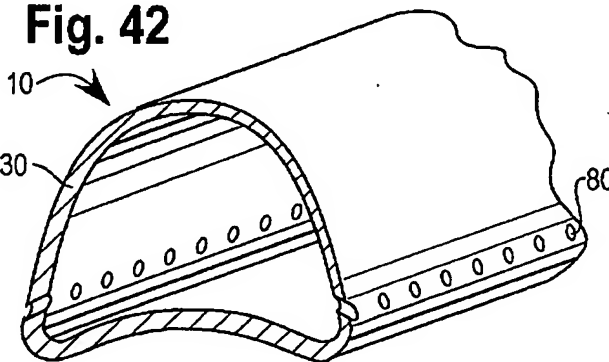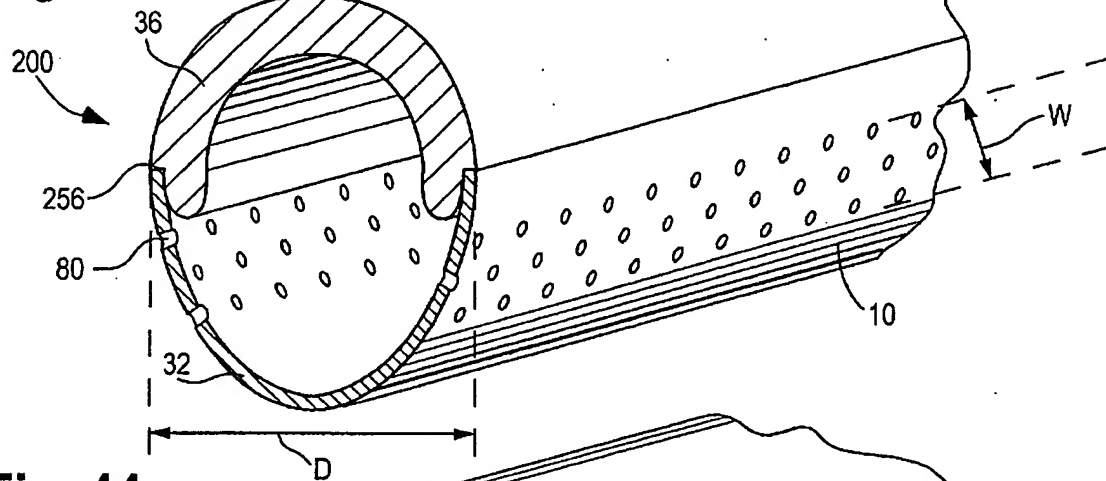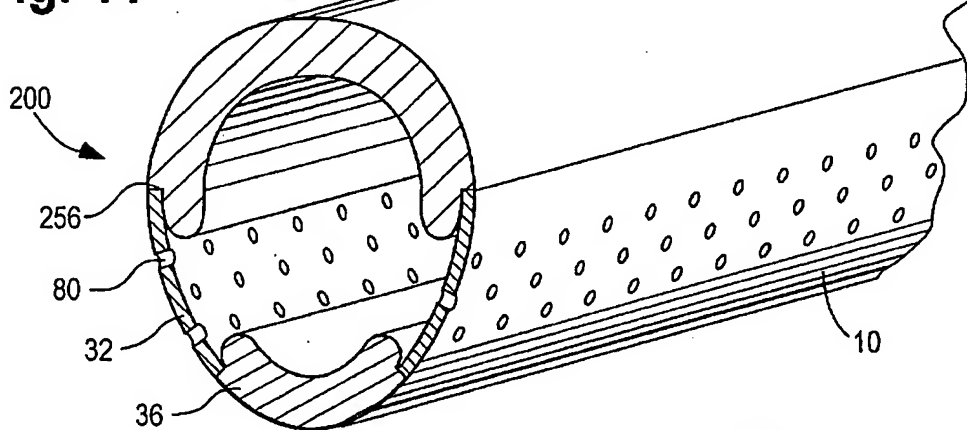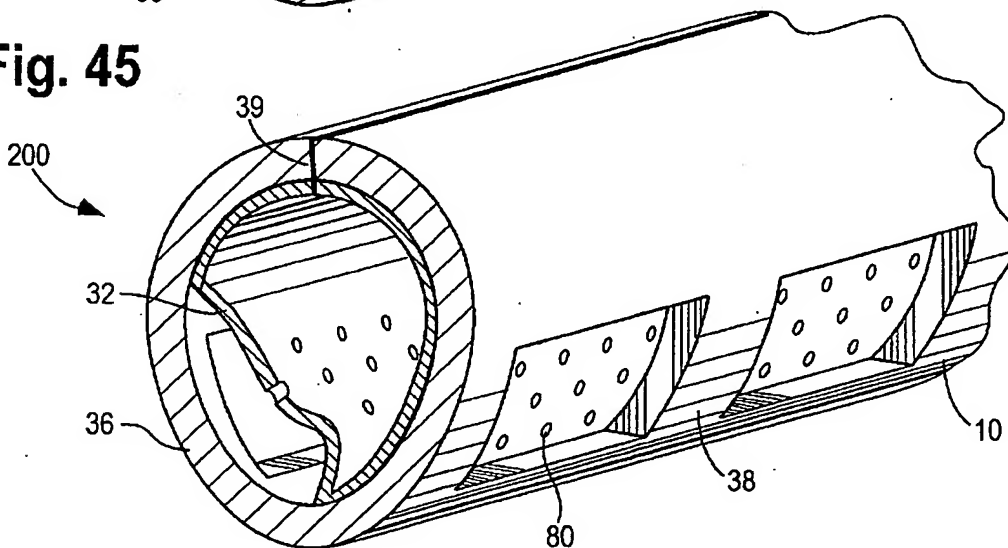## Fig. 59
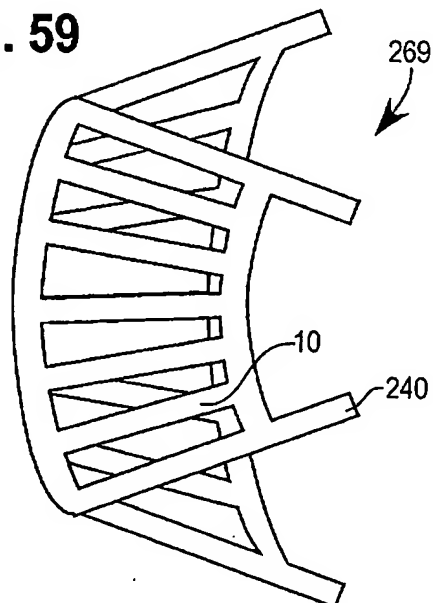
Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 60

Fig. 61

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 62

132   37   39

254   370

4

267
267
267

Fig. 135C

10
10
10

240

Fig. 135B   146

132

Fig. 63

80

10

903

10

Fig. 64

10

4

80

3

Method and Apparatus for Mixing Fluids
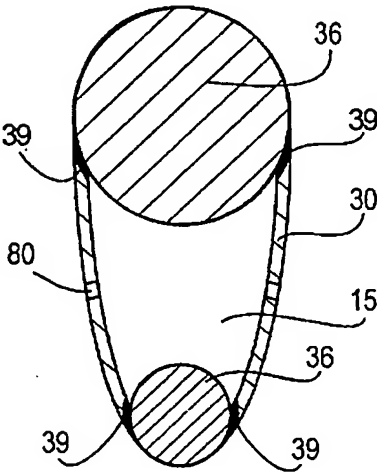Hagen et al.
Atty Docket:VAST.001CP2

18/28

Fig. 65

270

240

10

Fig. 66

271

265

10

240

273

Fig. 67

273

240

10

130

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 68

265

72

136
901→

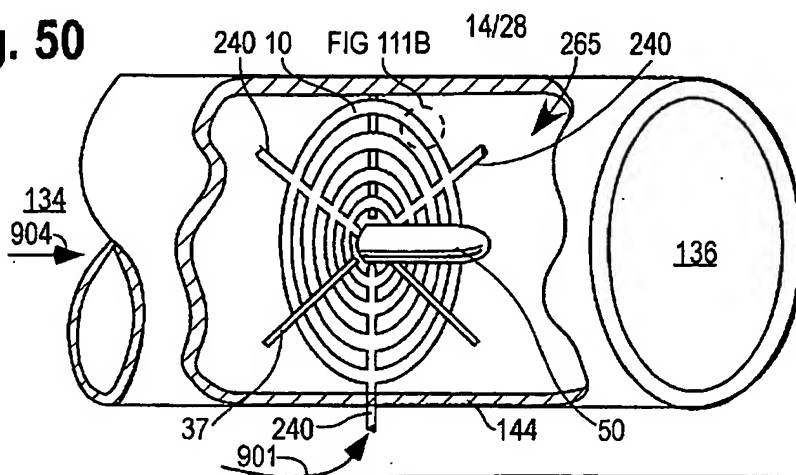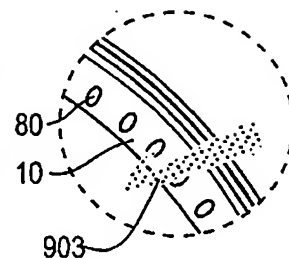134
904→

130

10 80 38

FIG. 51

130

Fig. 69

3→

4→
904

262 10

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 70

20/28

132

80
10
134
904
240
901
136

Fig. 71

132

134
80
904
240
10
901
136

Fig. 72

240
132

240
901
904
134
136
37
904
901
80
37

Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

21/28

Fig. 73-78

Fig. 78

Fig. 77

Fig. 76

Fig. 75

Fig. 74

Fig. 73

Maximum Design Pressure

All Orifice Flow

All Orifice Pressure

Part Orifice Flow

Minimum (Largest) Orifice Pressure

No Orifice Flow

0

22/28

Fig. 79

Fig. 80

Fig. 81

Method and Apparatus for Mixing Fluids
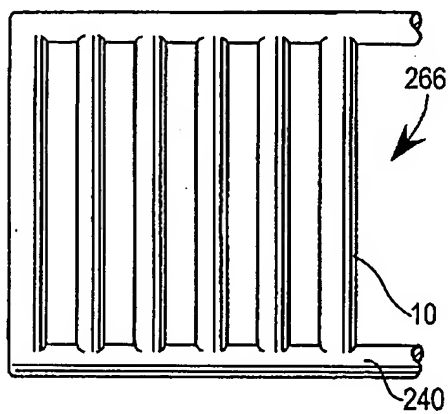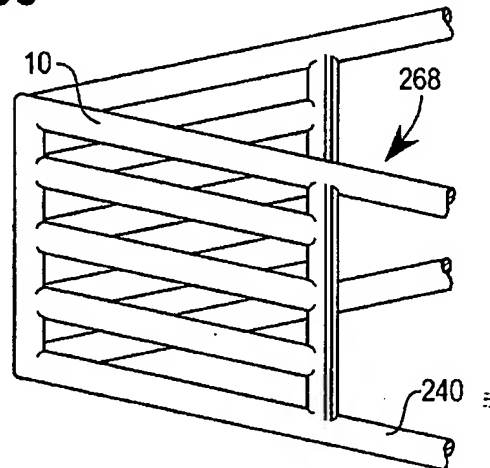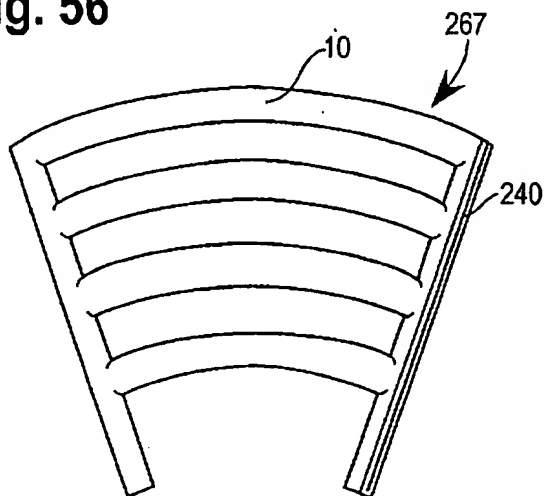Hagen et al.
Atty Docket:VAST.001CP2

Fig. 82
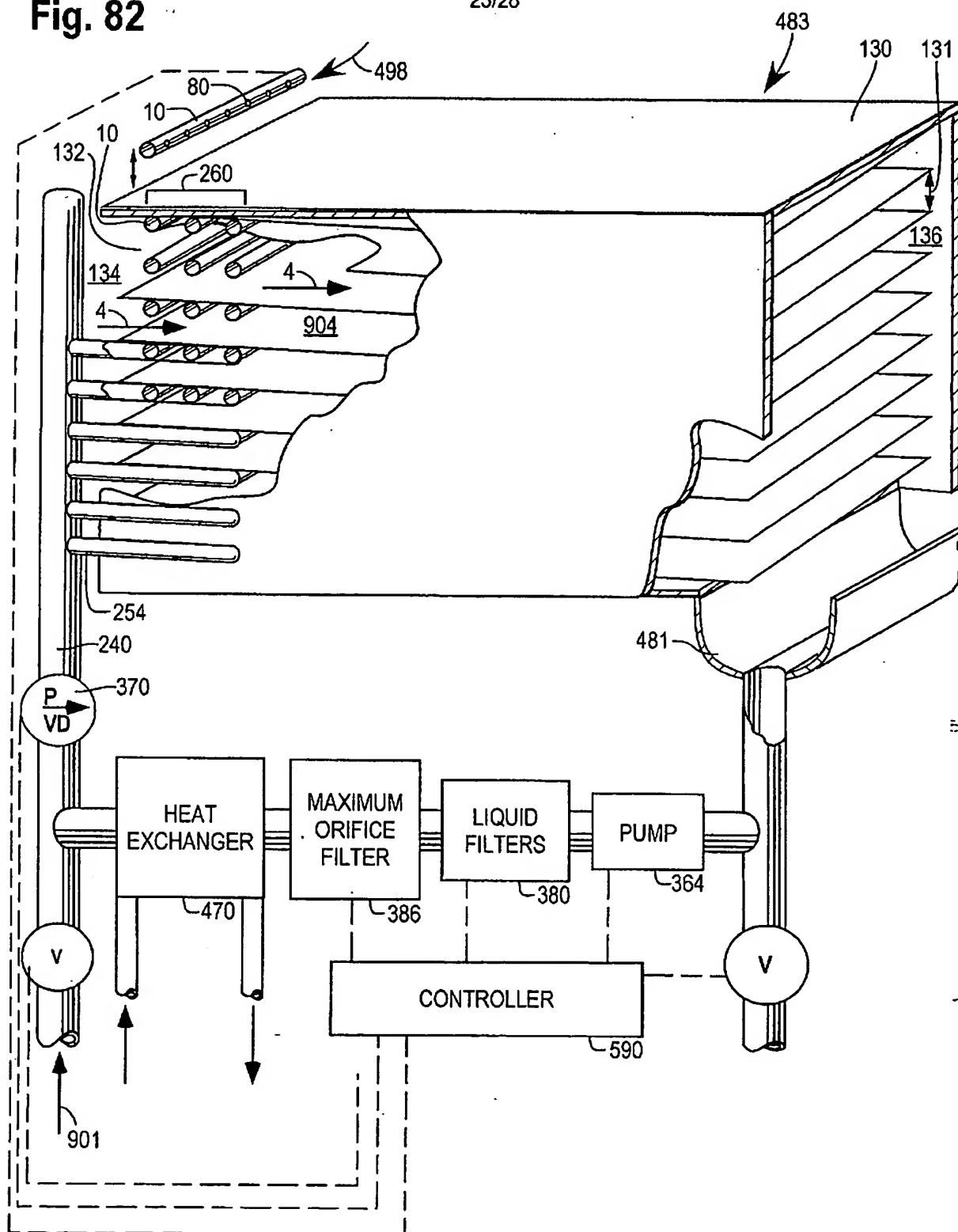
Method and Apparatus for Mixing Fluids
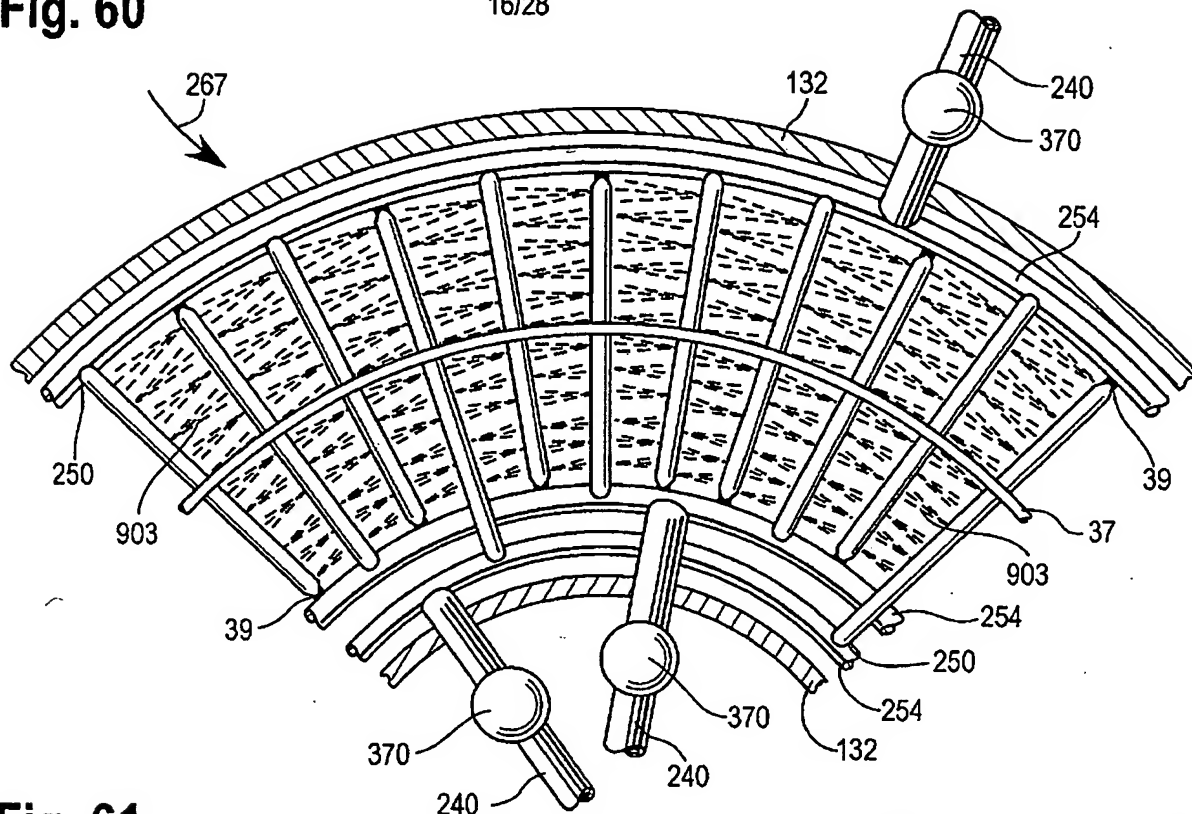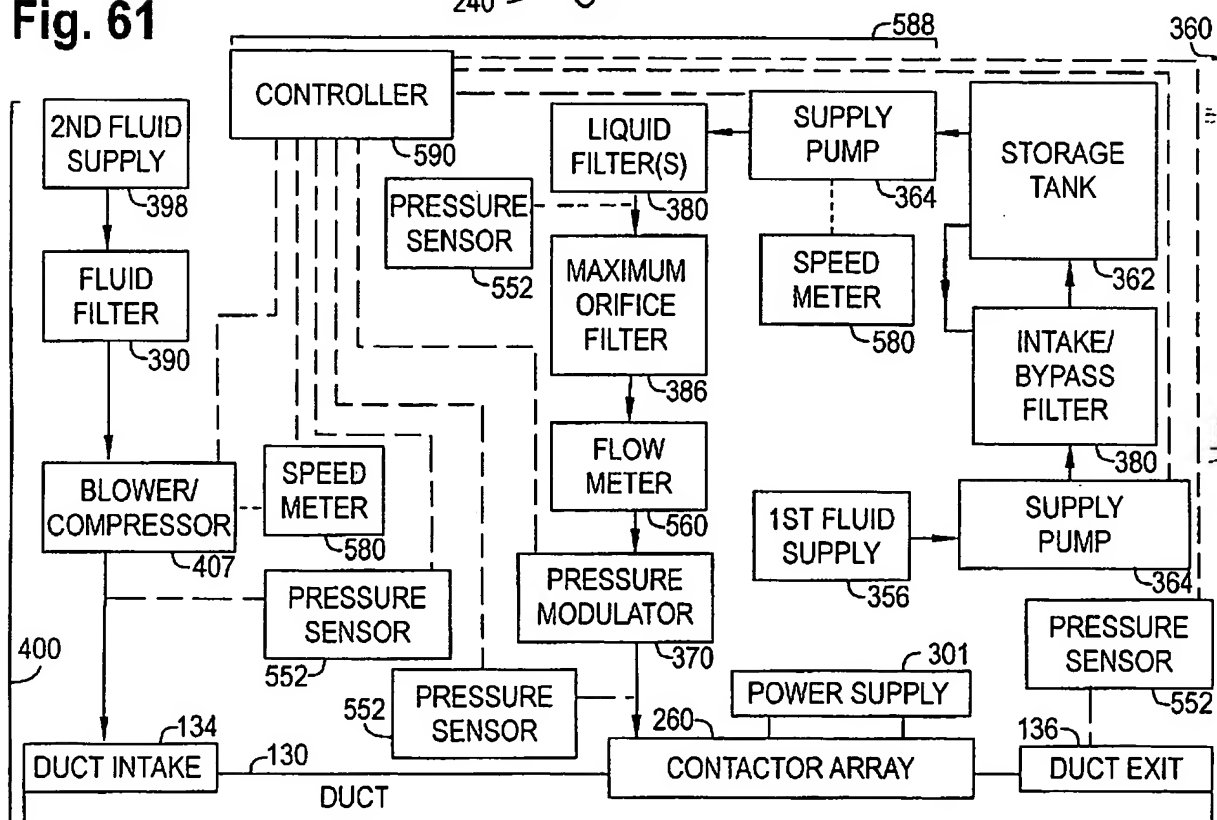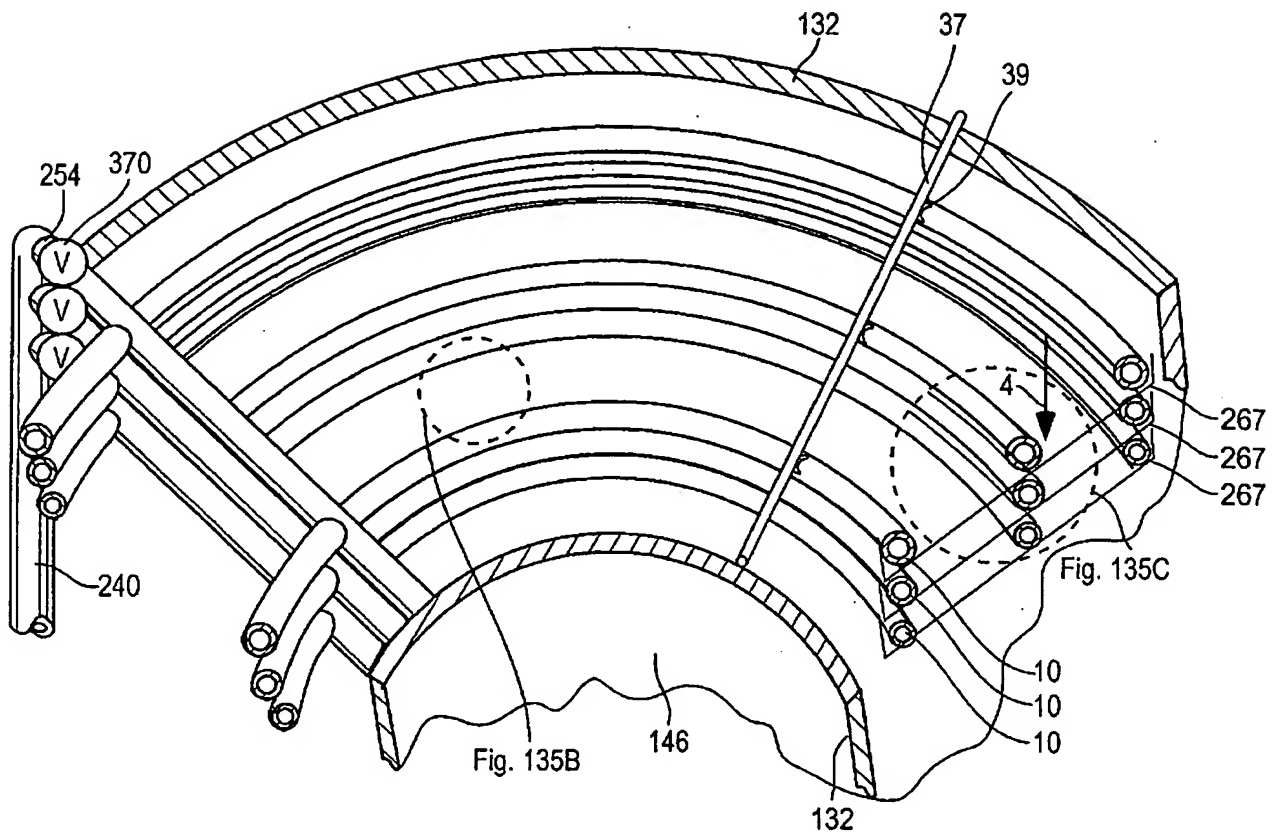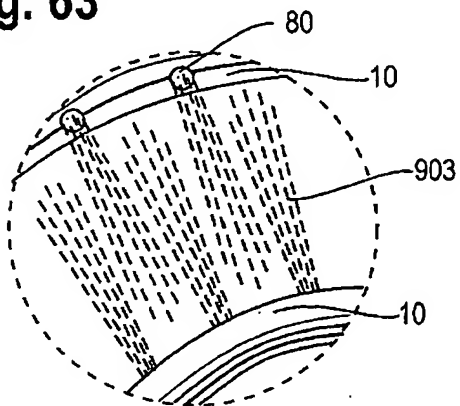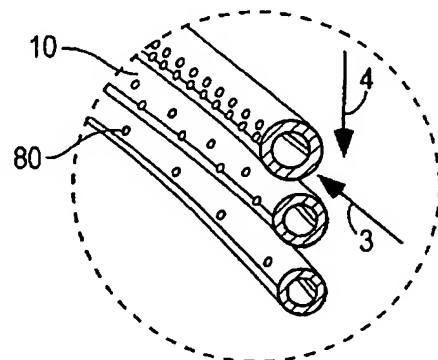Hagen et al.
Atty Docket:VAST.001CP2

Fig. 83

24/28
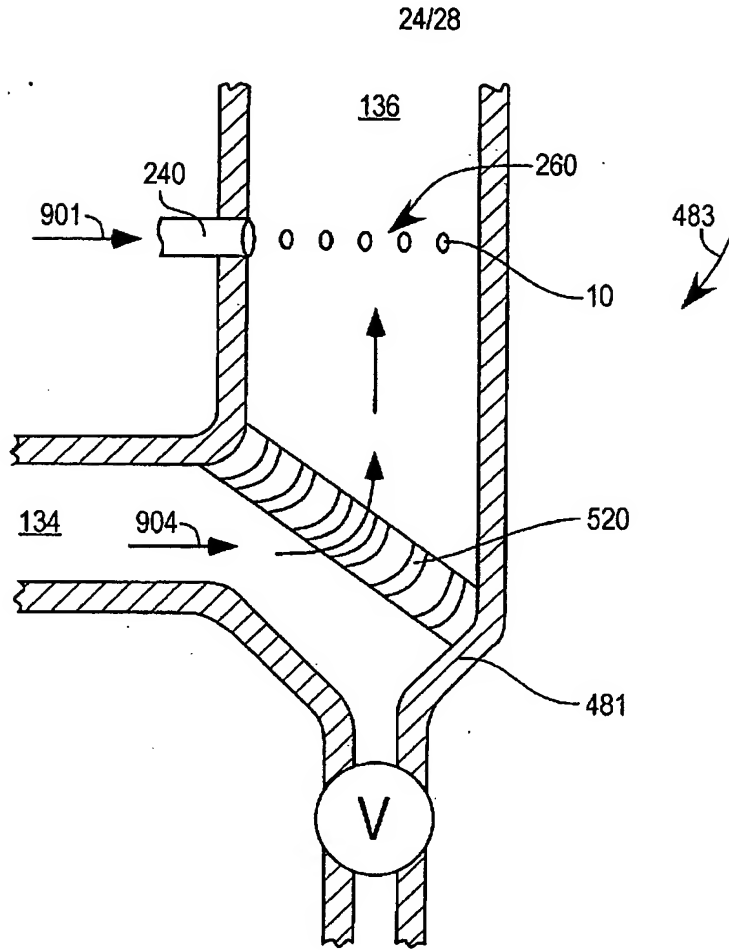
Fig. 84
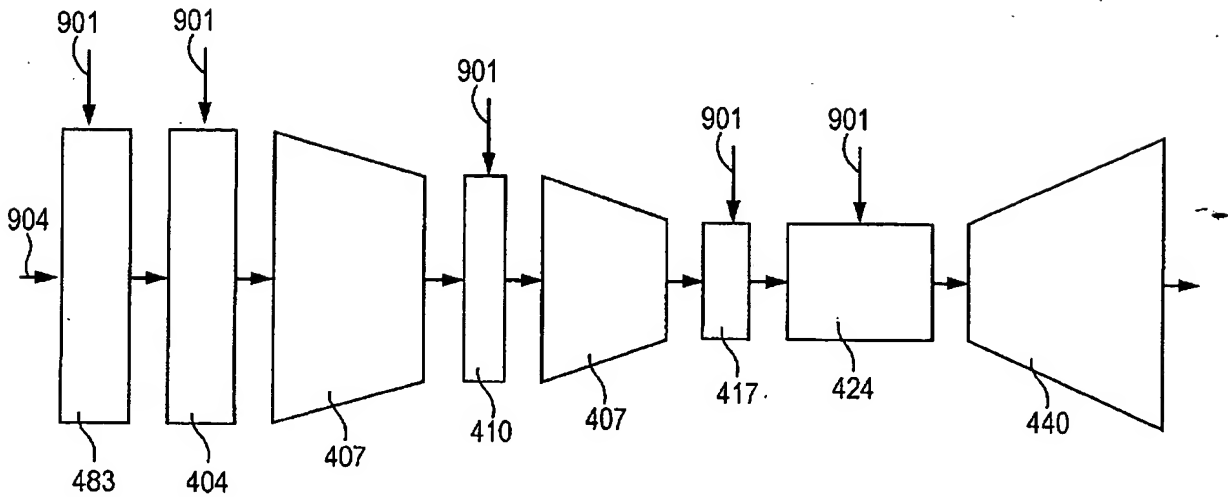
Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 85
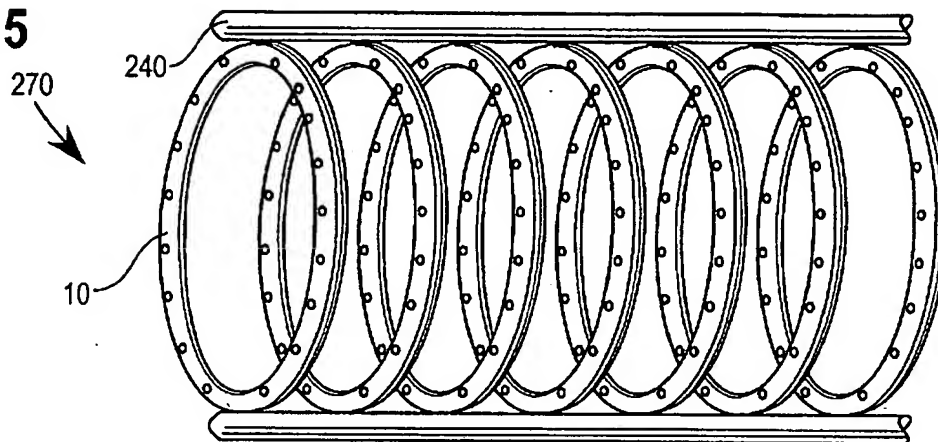
25/28

Fig. 86

Fig. 87

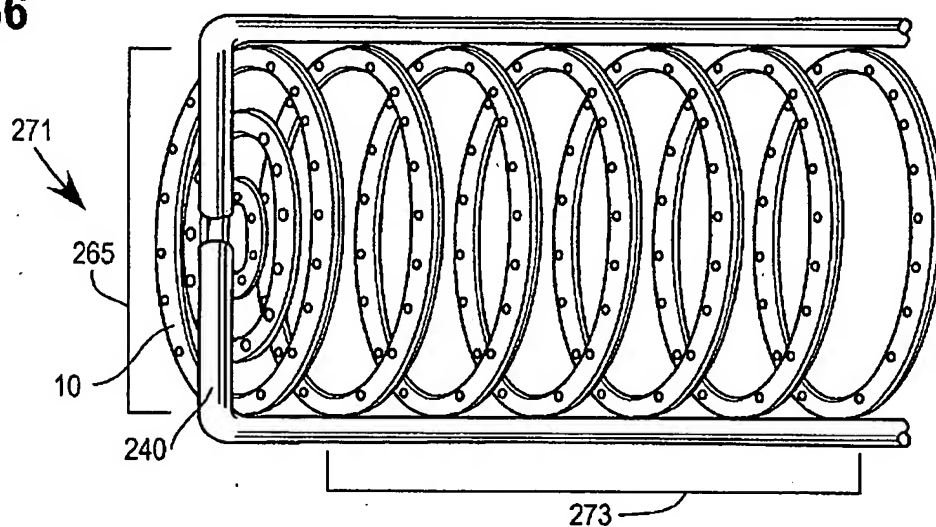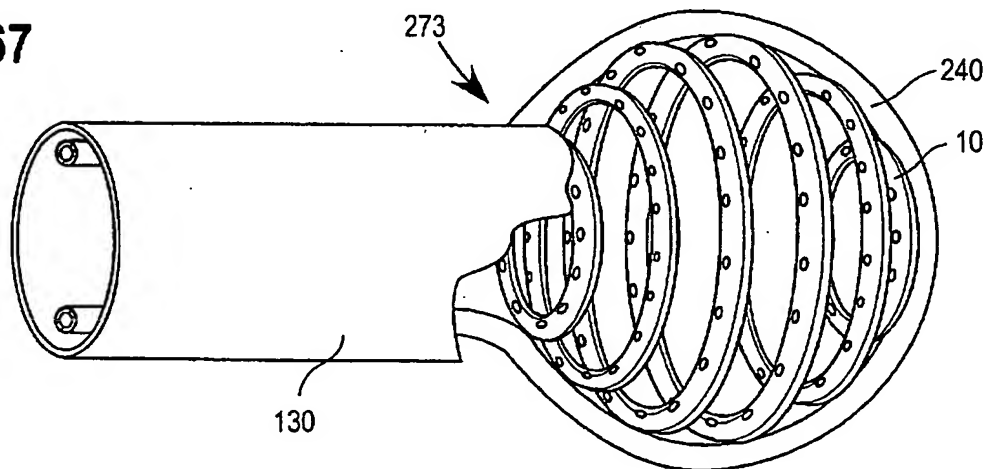Method and Apparatus for Mixing Fluids
Hagen et al.
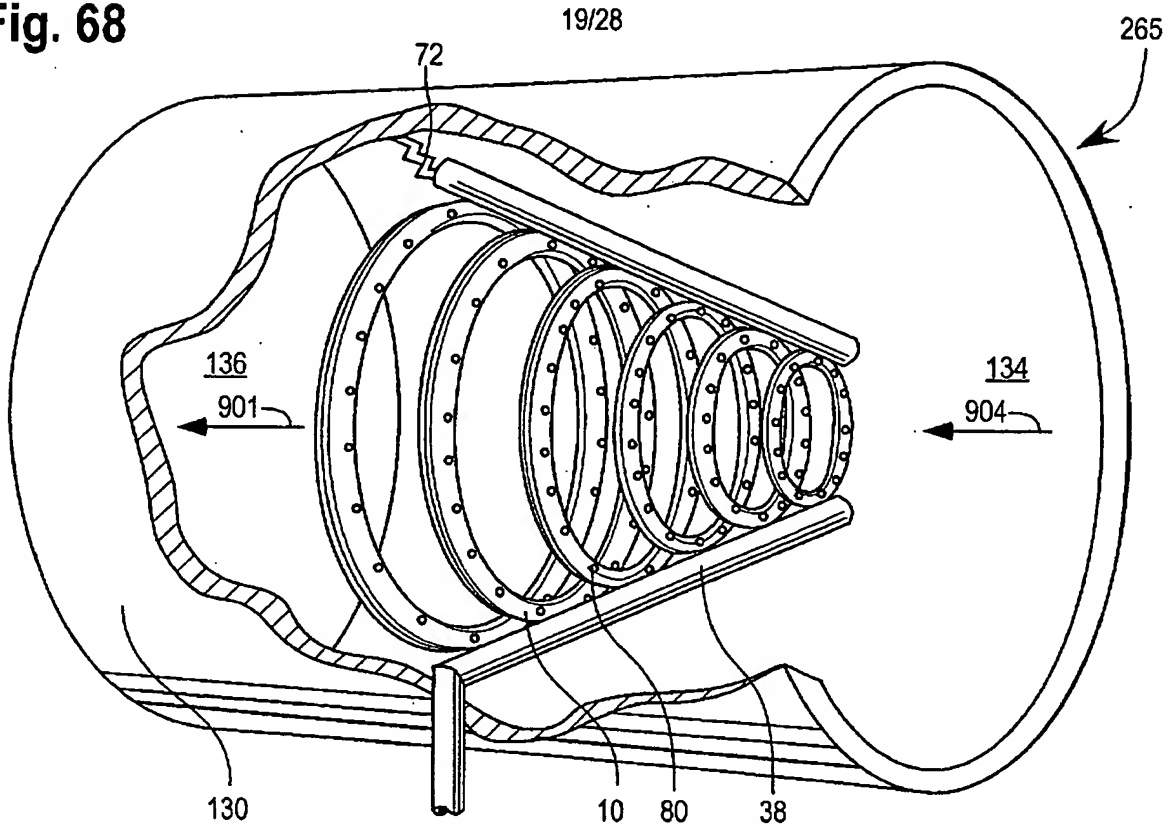Atty Docket:VAST.001CP2

Fig. 88

26/28 — 194

198

240   10   80   130

Fig. 89

136

134
4 →

254

10   130

240

Fig. 90

4 →

231

196   240

130

3
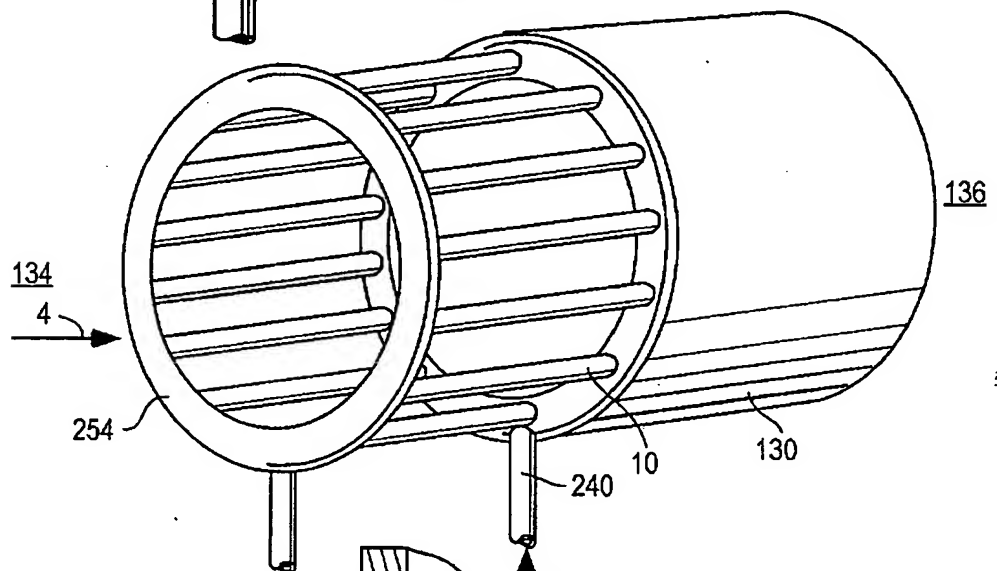
Method and Apparatus for Mixing Fluids
Hagen et al.
Atty Docket:VAST.001CP2

Fig. 91
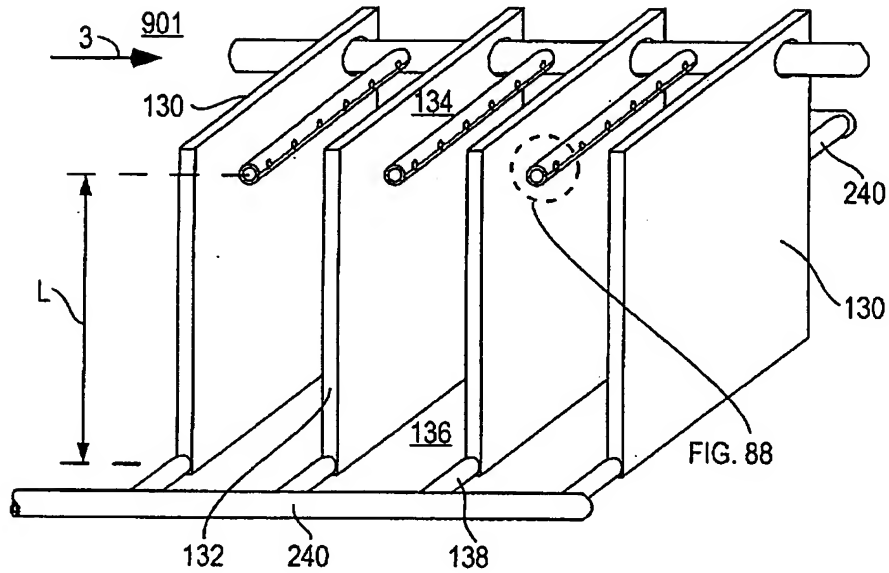
Fig. 93
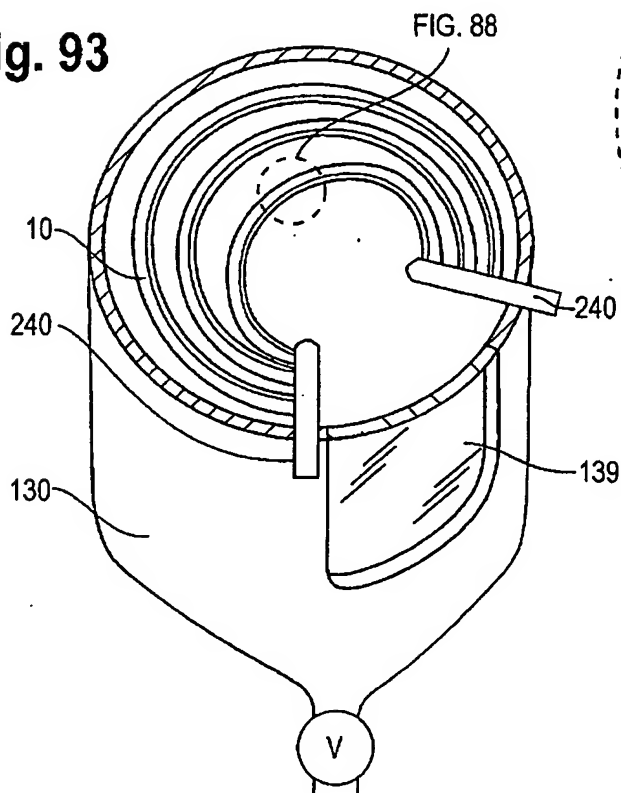
Fig. 92
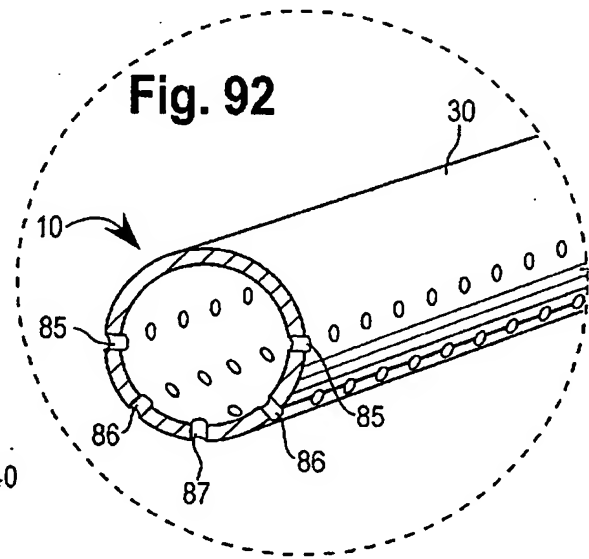
Method and Apparatus for Mixing Fluids
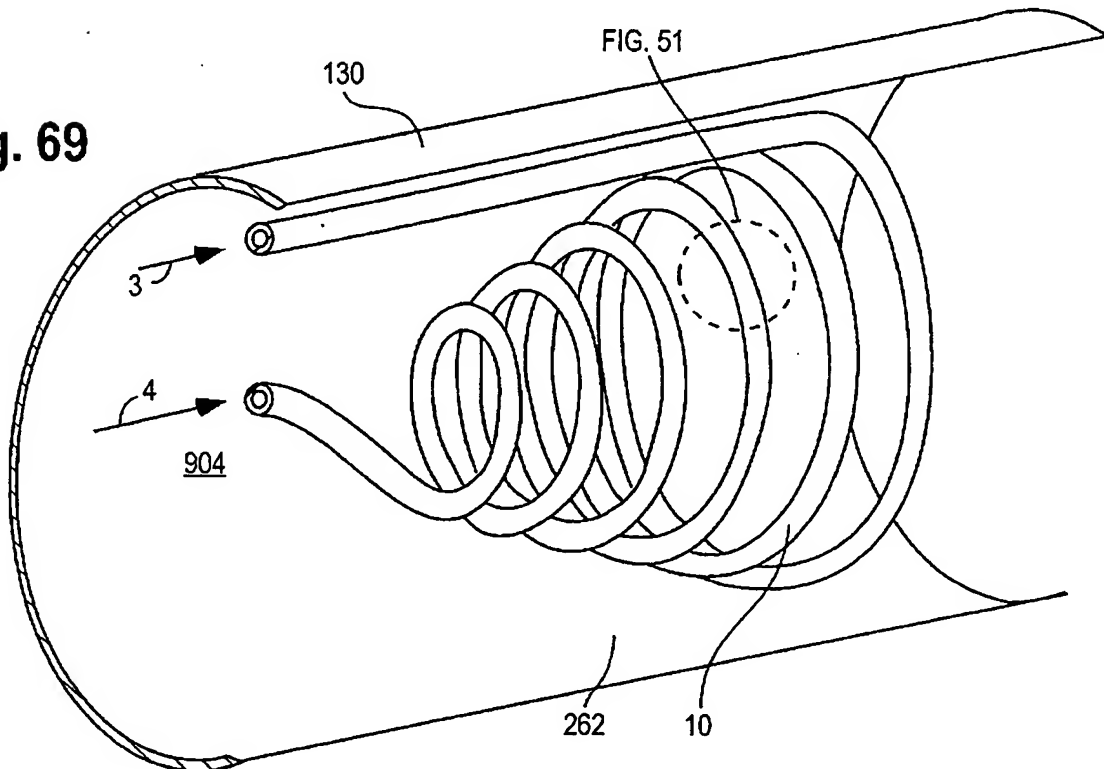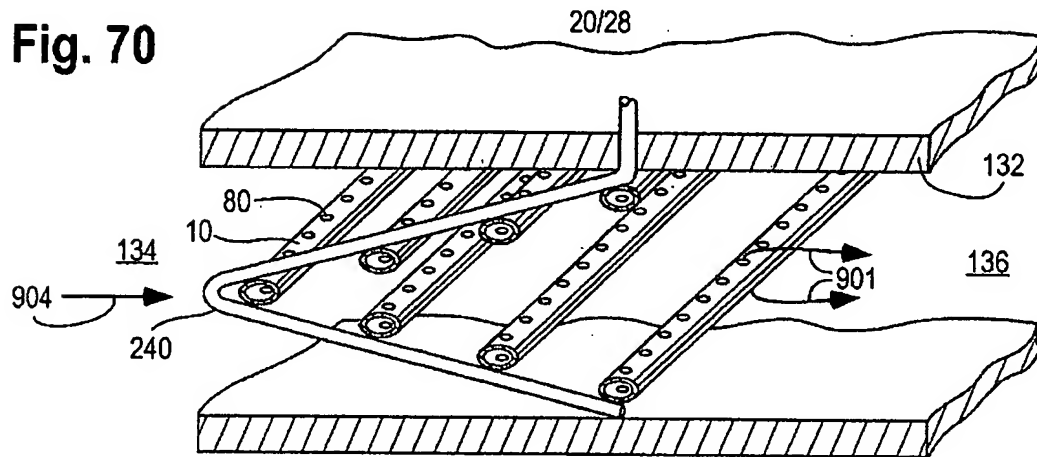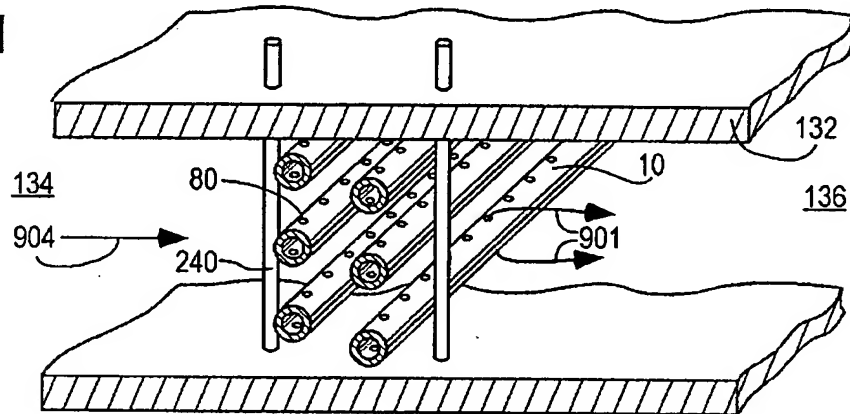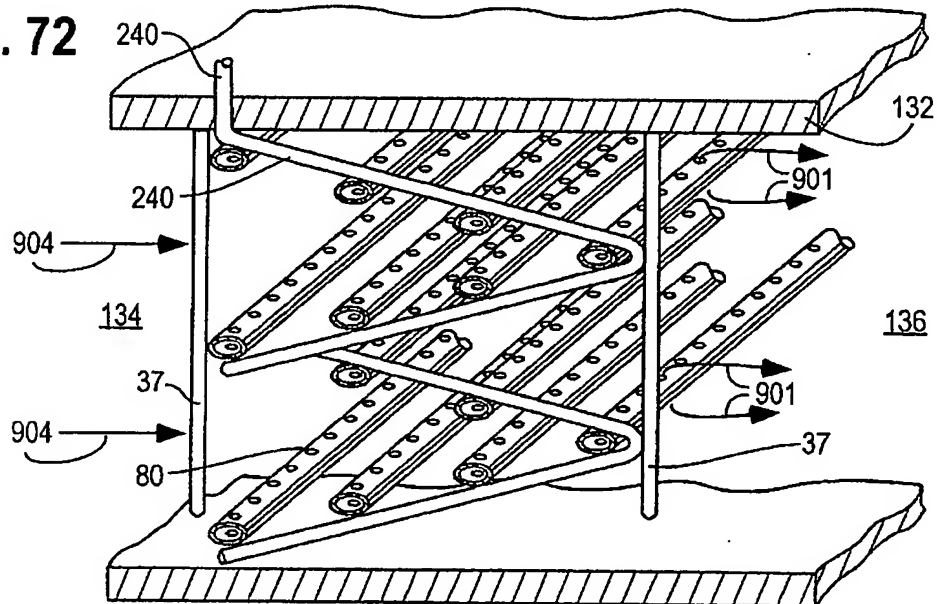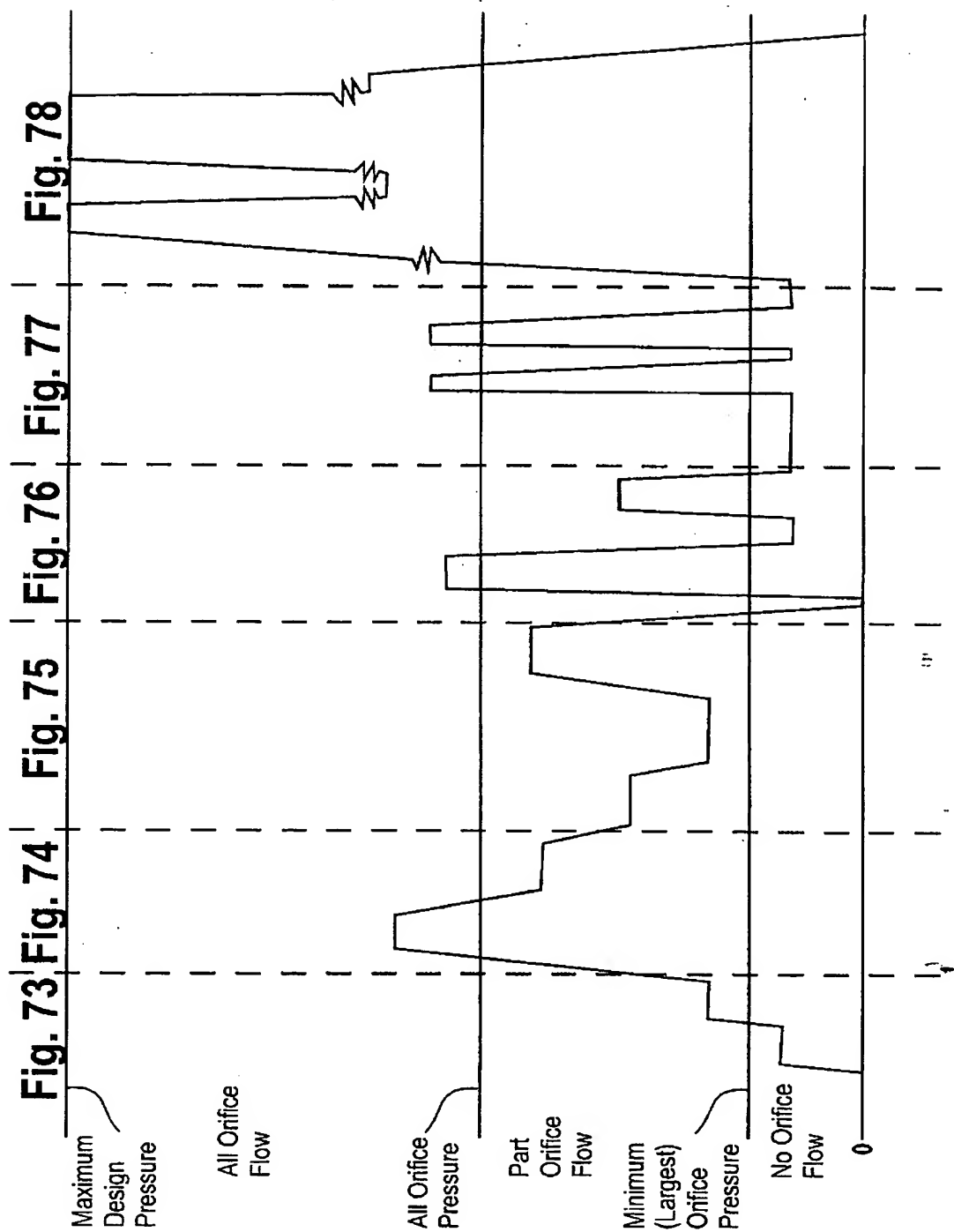Hagen et al.
Atty Docket:VAST.001CP2

Fig. 94

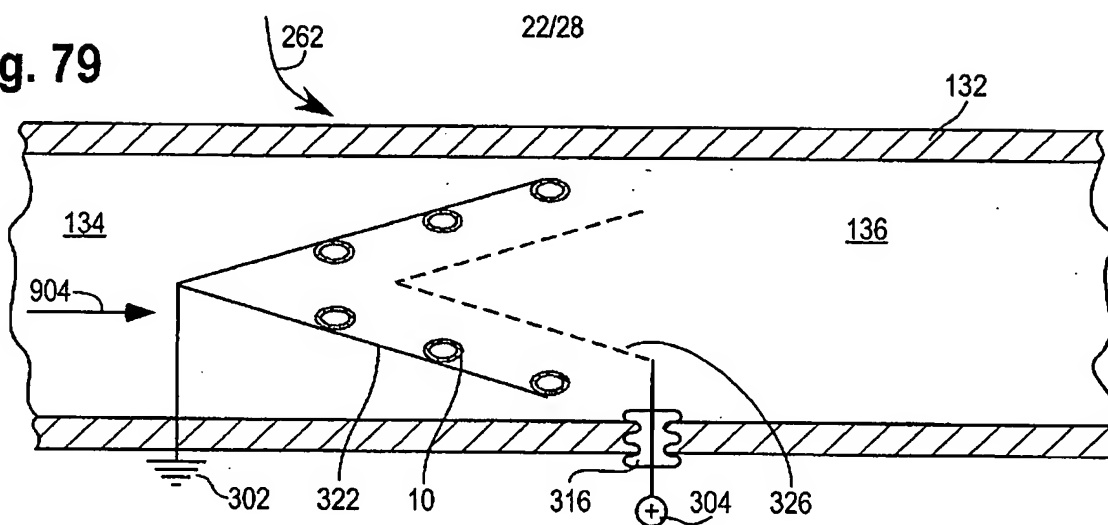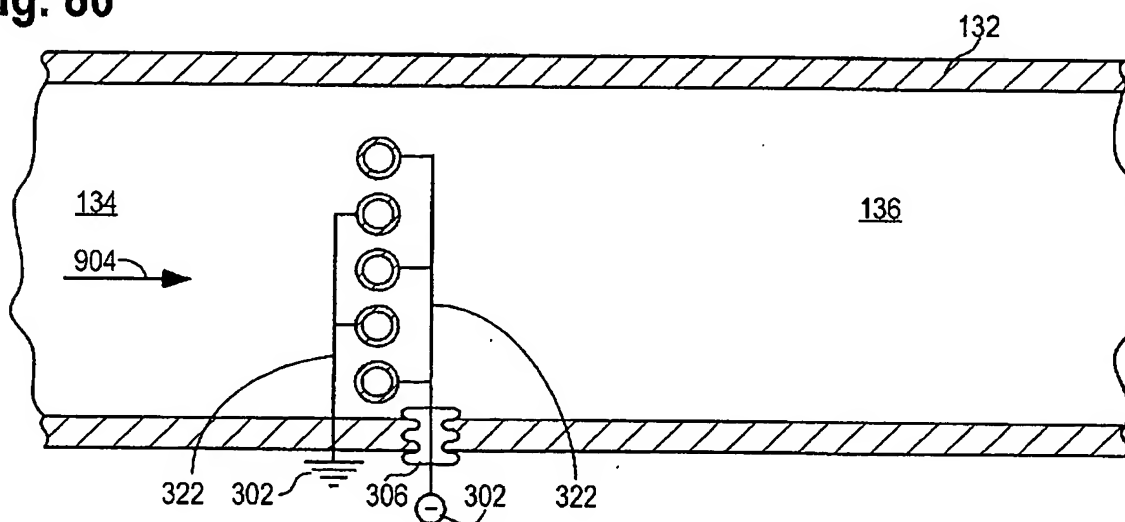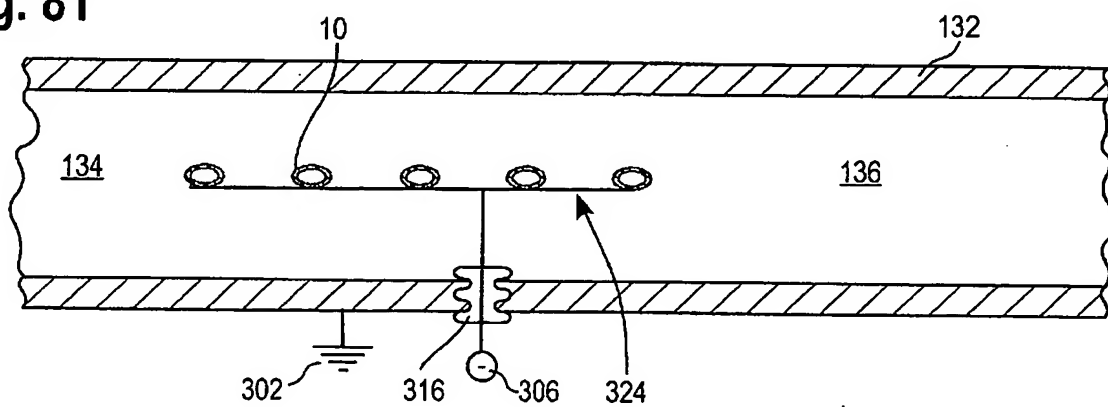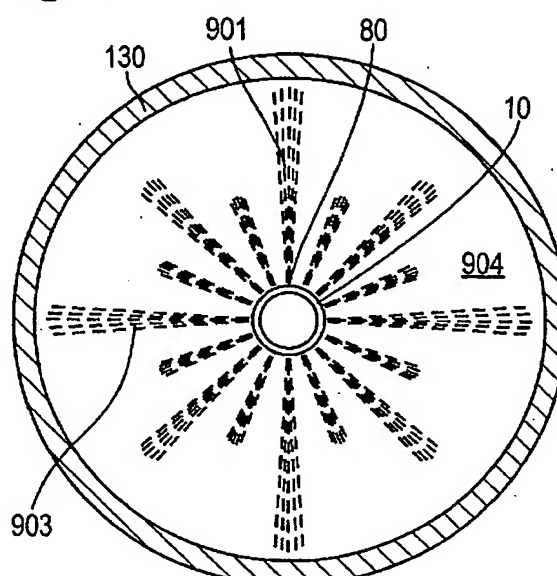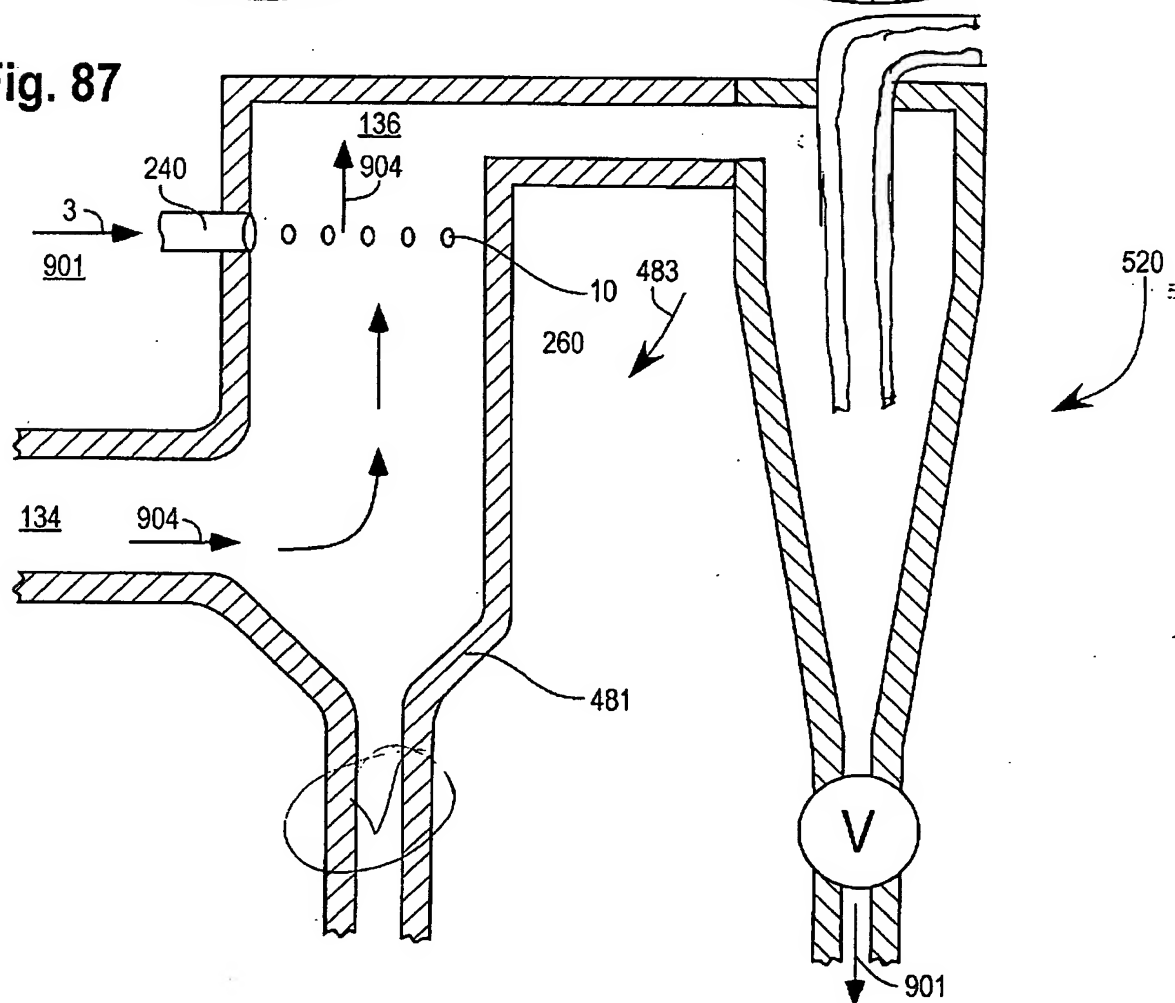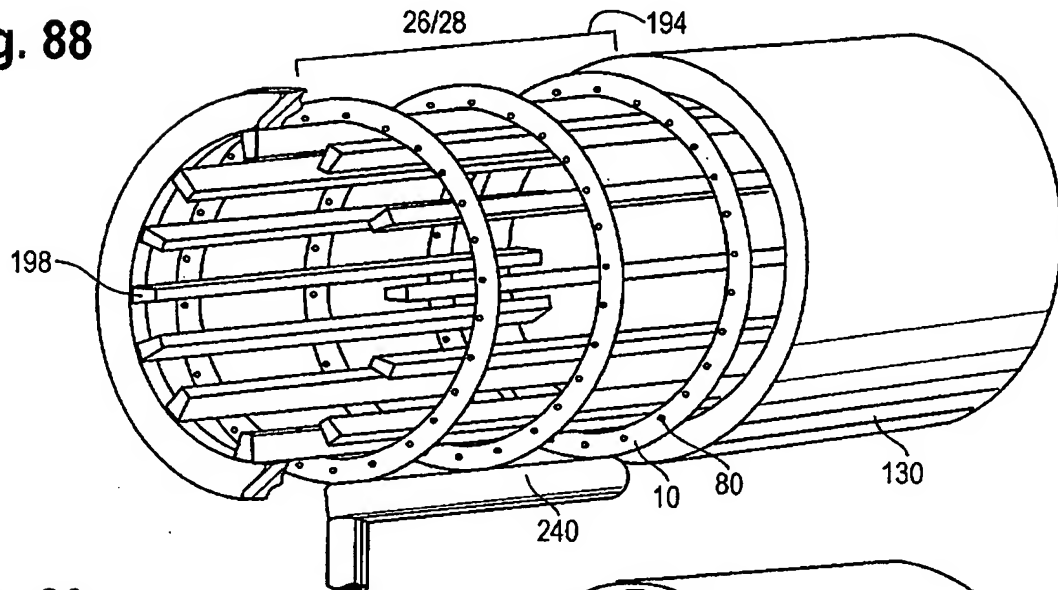## DISTRIBUTED CONTACTOR
MODELING METHOD

SET BOUNDARY CONDITIONS
FIRST & SECOND FLUID MASS FLOW
RATES, DENSITIES, VELOCITIES,
PRESSURES, ORIFICE DISCHARGE
COEFFICIENTS, TUBE TENSILE
STRENGTH

INITIALIZE PARAMETERS
PRESSURE, CONE ANGLE, ORIFICE
NUMBER, ORIFICE SPACING,
ORIFICE DIAMETER, PENETRATION,
TUBE GAP, WALL THICKNESS,
TUBE DIAMETER, INJECTION
VELOCITY, TUBE LENGTH

MODEL EQUATIONS
DESIGN EQUATIONS
HOLE SPACING, TUBE LENGTH, TUBE SPACING

FLOW EQUATIONS
ORIFICE FLOW MODEL
SPRAY PENETRATION CORRELATION
CONE ANGLE CORRELATION
COMPOSITION MASS FLOW RATE RELATIONS

APPLY CONTRAINTS e.g.
TRANSVERSE DISTRIBUTION(S) OF SPRAY PENETRATION,
SECOND TO FIRST FLUID COMPOSITION
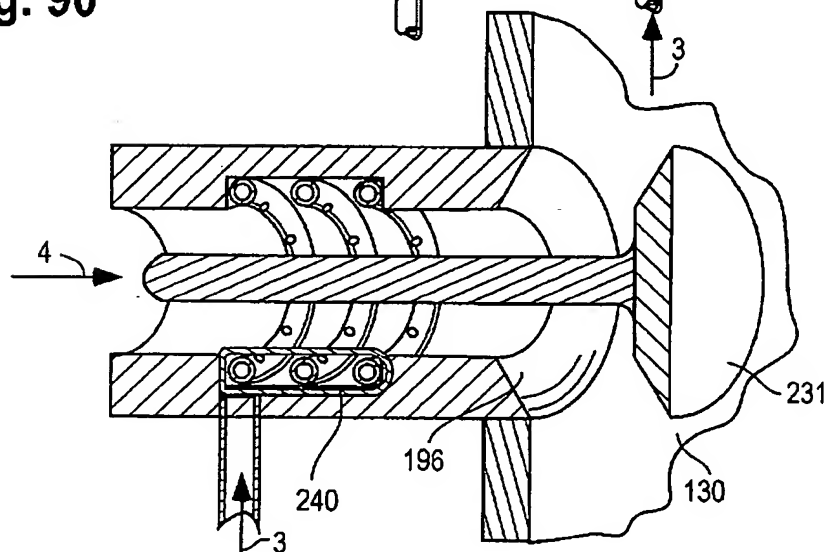HEAT TRANSFER TIME & DISTANCE AND/OR
EVAPORATION TIME & DISTANCE
TUBE MAXIMUM PRESSURE, TUBE DIAMETER
MAXIMUM ORIFICE LENGTH/DIAMETER

OUTPUT VALUES
TRANSVERSE DISTRIBUTION(S) OF FLUID PRESSURE,
ORIFICE NUMBER, ORIFICE SPACING, ORIFICE DIAMETER,
ORIFICE ORIENTATION, ORIFICE LENGTH/DIAMETER,
SPRAY CONE ANGLE, SPRAY PENETRATION, INJECTION VELOCITY,
TUBE GAP & TUBE WALL THICKNESS; & TUBE DIAMETER & TUBE LENGTH